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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 169.

B. T. GALLOWAY, *Chief of Bureau.*

VARIEGATED ALFALFA.

BY

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FORAGE-CROP INVESTIGATIONS.

ISSUED FEBRUARY 3, 1910.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1910.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., October 9, 1909.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin 169 of the special series of this Bureau the accompanying manuscript, entitled "Variegated Alfalfa." This has been prepared by Mr. J. M. Westgate, Agronomist in Charge of Alfalfa and Clover Investigations, Forage-Crop Investigations, and has been submitted by the Agrostologist in Charge of Forage-Crop Investigations with a view to publication.

The studies made in connection with the comparative tests of alfalfa varieties have disclosed a hardy, drought-resistant race which apparently owes its origin to the crossing of ordinary alfalfa with the hardy, yellow-flowered alfalfa of Europe and Asia. In addition to its superior hardiness and drought resistance it possesses other characteristics which serve to distinguish it from ordinary alfalfa. The possibilities of this group of variegated alfalfas for use in extending the production of the crop in sections where the climate is too severe for ordinary alfalfa, together with its great variability, which affords excellent opportunities for breeding and selection, make the publication of these studies desirable.

Very respectfully,

A. F. Woods,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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VARIEGATED ALFALFA.

INTRODUCTION.

In connection with investigations concerning alfalfa there have appeared from time to time isolated instances of fields which have been notably superior to near-by fields of ordinary alfalfa. In one instance, namely, the Grimm alfalfa of Minnesota, the progeny of a single field has spread and attracted much merited public attention by reason of its hardiness. Special attention has naturally been called to such fields as are located in sections where ordinary alfalfa is not altogether successful. Comparative studies have shown that these fields agree in showing a considerable percentage of flowers of some other color than the violet of ordinary alfalfa. Fields which resemble these hardy fields in general appearance have also been discovered in the recognized alfalfa districts, but they have attracted much less attention owing to the success of ordinary alfalfa in such districts. A study of such strains as have become more or less well known, together with several isolated fields, has revealed the fact that they may all be classed in the same botanical category as "variegated alfalfa." The agronomic tests, while not completed as yet, indicate that from similar sources these variegated strains are hardier than the nonvariegated strains. The designation "hardy alfalfa" has already been applied in part to two of the strains under consideration, Grimm alfalfa and commercial sand lucern. The alfalfas which have been identified with this group are Grimm alfalfa, commercial sand lucern, and much of the so-called Canadian alfalfa, together with a number of less well-known strains.

In addition to the fields of hardy alfalfa which have commanded attention in this country and Canada, it has been found that certain regional lots, secured chiefly from central European sources, possess the same characteristics and assist materially in explaining the origin of the entire group. Investigations concerning the history and characteristics of this alfalfa indicate its probable origin and afford a logical explanation of the remarkable variations that it presents.

Variegated alfalfa has apparently originated by the natural hybridizing of ordinary alfalfa with the hardy yellow-flowered alfalfas of

Eurasia. The natural hybridizing of the two species has given rise to a series of crosses which have subsequently intercrossed among themselves and with the original parental stocks, especially ordinary alfalfa, the pollen of which is probably prepotent. In this way there has been produced a group of multiple crosses which present a mass of widely varying forms. These, while showing much diversity in appearance, include a considerable proportion which possess the ability to withstand cold, drought, and unfavorable soil conditions better than ordinary alfalfa.

The hybrids have apparently been produced wherever the two parents have come in contact. These forms, as evidenced by the variation in the flower color, are reported to have been noted by the Swiss botanist, Casper Bauhin, who was born in the year 1560 and died in 1624.[a] This observation was made in southern France, but the perfect success with which ordinary alfalfa is produced there gave little opportunity for the establishment or recognition of hardy races by selective acclimatization, as has been the case under more severe climatic conditions, where the hybrid forms possess advantage over the ordinary alfalfa. A study of the parental species and their hybrids is necessary to indicate the relationships of "variegated alfalfa."

THE YELLOW-FLOWERED FALCATE-PODDED ALFALFA (MEDICAGO FALCATA, L.) AND ITS ALLIES.[b]

An examination of several different introductions of yellow-flowered alfalfa secured from various points in Europe and Asia indicates that there are several forms to be recognized. These have usually been grouped under the one species, *Medicago falcata*, and as far as the purposes of the present bulletin are concerned they may be so treated here. The original binomial description of *Medicago falcata* is very short and states simply that the peduncles which bear the racemes of flowers are arranged racemosely on the stalks, the pods crescent shaped, and the stems prostrate.[c] The flowers of this species are uniformly yellow and are borne in racemes of from five to twenty flowers each. The pedicels average about one-fourth longer than the calyx tubes, while the calyx teeth average about one-sixth longer than the calyx tubes. The pods are sickle shaped, reticulately veined, and generally very dark colored when mature. The three leaflets vary from obovate to linear cuneate and are usually

[a] Martyn. Flora Rustica, 1792, vol. 3, p. 87; also Pinax, p. 330.

[b] Hansen, N. E. The Wild Alfalfas and Clovers of Siberia, with a Perspective View of the Alfalfas of the World. Bulletin 150, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1909.

[c] Medicago pedunculis racemosis, leguminibus lunatis, caule prostrato. Linnæus, Species Plantarum, 1753, vol. 2, p. 779, and Flora Suecica, par. 620; also Dalibard, Floræ Parisiensis Prodromus, Paris, p. 229.

either deeply notched or mucronate at the apex. Many of the plants show a tendency to produce occasional leaves with supernumerary leaflets. The decumbent or prostrate stems show a decided tendency to be four angled and are somewhat woody at the base when old. (See Pl. I, fig. 1.) The variations noted in the different forms are principally in the shape of the leaves and flowers and in the habit of growth of the individual plants, which vary from prostrate to ascending. The species is widely distributed throughout Europe, except in the extreme north, and extends eastward at least to the Baikal Mountains in eastern Siberia.[a] It has also been reported from China.[b] It normally grows in rather exposed and unfavorable situations. Where it occurs in any considerable quantity it is sometimes mown for hay. Instances are on record where seed of the wild plants have been gathered and the resulting plants domesticated.[c]

The chief drawbacks to the agronomic utilization of this species are its poor seeding habits, its light yield of hay, and the tendency of its stems to be prostrate or procumbent. The quantity of seed produced by the plants is not only small, but it shatters badly. The principal value of this species lies in its power to withstand severe conditions as regards soil and climate, as it is thus enabled to grow on soils unfavorable to the successful growth of ordinary alfalfa. Its ability to thrive under severe conditions without reseeding for long series of years has been a matter of note.[d]

The rôle that *Medicago falcata* has played in hybridizing with the ordinary alfalfa and producing progeny combining the desirable characteristics of both parents is of great agronomic importance.

ORDINARY ALFALFA (MEDICAGO SATIVA, L.).[e]

The original binomial description of *Medicago sativa* states that the peduncles bearing the flower racemes are arranged racemosely on the

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[a] Stebler and Volkart. Die besten Futterpflanzen, 3d ed., 1908, p. 105.

[b] Bretschneider. History of European Botanical Discoveries in China, vol. 2, p. 859.

[c] Metz and Co. Berichte über Nutzpflanzen, Berlin, 1868, p. 13. In the account given it is noted that seed was gathered from plants growing in exposed situations and from very sterile soil. The seed was sown in part on poorly drained and in part on thin, dry soil. The results were very satisfactory and the seedings were continued, as ordinary alfalfa had been found unable to succeed under the conditions present.

[d] Stebler and Volkart, loc. cit. These authors state that a local seeding made at Zürich, Switzerland, in 1885 was still standing in 1908, while ordinary alfalfa planted at the same time disappeared after six years. Another seeding of *Medicago falcata* made on the experimental field at Furstenalp, Switzerland, 1,780 meters above sea level, had in 1908 lasted twenty years, in spite of the rough situation and damp soil and without having reseeded itself.

[e] See Coburn, F. D., The Book of Alfalfa, 1906; Scofield, C. S., The Botanical History and Classification of Alfalfa, Bulletin 131, pt. 2, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908; Westgate, J. M., Alfalfa. Farmers' Bulletin 339, U. S. Dept. of Agriculture, 1908; and Wing, Joseph E., Alfalfa Growing in America, 1909.

stems, the pods coiled, and the stems erect and glabrous.[a] The flowers of this species are normally violet and are borne in racemes of from eight to twenty-five flowers each. The pedicels average about two-fifths shorter than the calyx tubes, while the calyx teeth average about one-third longer than the calyx tubes. The pods are coiled two to four times in close spirals, are delicately veined, and brown in color when mature. The three leaflets are usually obovate to lanceolate and are toothed or dentate toward the apex. The individual plants show but slight tendencies to produce leaves with supernumerary leaflets. The stems are nearly erect, show little tendency to become woody when old, and are slightly inclined to be four angled. (See Pl. I, fig. 4.)

This species, whose probable original home was in Persia, has since become widely spread, especially in those parts of the temperate world where agricultural operations are important. Its extension into the sections occupied by the wild forms of the yellow-flowered alfalfas is of special significance in connection with the studies as to the multiple origin of the hybrid variegated alfalfas. The agronomic value of alfalfa is probably second to that of no other forage plant in the world. It is possessed of a wide adaptability to different climates and soils, but unfortunately is not able to withstand the severe conditions presented by some of the agricultural districts, especially along the northern border of successful agricultural operations, where the winters are severe, and in the semiarid regions, where the lack of sufficient moisture prevents the production of profitable crops of hay. This lack of complete adaptation to all agricultural districts has handicapped the extension of ordinary alfalfa over large sections where only a slight increase in hardiness or drought resistance would enable it to be successfully produced.

HYBRID INTERMEDIATE FORMS OF ALFALFA (MEDICAGO SATIVA VARIA (MARTYN) URBAN; MEDICAGO FALCATA × MEDICAGO SATIVA, REICHB.).[b]

There has been much confusion in botanical literature in regard to the proper classification of the many varied forms of alfalfas which have appeared where the ordinary alfalfa and the yellow-flowered species have been associated.[c] The nonstability of the different forms readily accounts for this botanical confusion. The first botan-

[a] Medicago pedunculis racemosis, leguminibus contortis, caule erecto glabro. Linnæus, Species Plantarum, 1753, vol. 2, p. 778, and Hortus Cliffortianus, p. 377; also Royen, Floræ Leydensis Prodromus, p. 281.

[b] In the present publication the term "intermediate" is used to designate the forms occupying the middle third of the space between the two parents as regards their general characters.

[c] Stebler and Volkart, loc. cit.

ical description of what appears to be this hybrid was by Martyn, whose description concerns itself principally with the noteworthy variation to be observed in the flowers of the different individuals, as follows:[a]

Medicago varia (species or rather variety).—Various flowered medick. Yellow medick varies much in the color of its flowers, which are sometimes whitish, quite white, or greenish. The variety here figured is remarkable in having flowers of colors so different as blue and yellow on the same stalk. Casper Bauhin says that it is found in the south of France with whitish yellow, green, blue, purple, black, and variegated flowers, but he does not affirm that these different colors are on the same plant. Mr. Ray observed it with a purple flower, between Norwich and Lynn, and doubted whether it was not the true lucern in a wild state. The stipules are narrower in this than in the foregoing [*Medicago sativa*], but whether this difference be permanent or not we can not say.

The next botanical description that in all probability refers to one of the hybrid forms is the *Medicago media* of Persoon; at least botanists have generally considered that Persoon's description refers to the hybrids between *Medicago sativa* and *Medicago falcata*. This name has had common acceptance in many floras, but owing to the priority of the name assigned by Martyn this has come to be recognized as a synonym of *Medicago sativa varia*. In the description of *Medicago media* the characteristics are noted as follows: The peduncles bearing the flower racemes are arranged subcorymbosely on the stems; the flowers are pale blue, but at length become yellowish; the leaves are wedge shaped to linear, notched or retuse at the apex and hairy beneath.[b]

Among the other names which have been assigned to these forms are *Medicago sativa* L., var. *versicolor* Ser.; *Medicago falcata* L., var. *hybrida* Gaud.; *Medicago falcata* × *Medicago sativa* Reichb.; and *Medicago intermedia* Schultes.[c] These forms appear in most respects to be intermediate between the two species just discussed. The flowers, however, show a great tendency to vary in color, especially on different plants. In addition, the color in the individual flower is apt to show a progressive change in color as it becomes older. The flowers of a single individual may, in fact, run the gamut of variation from violet through blue and green to yellow. The racemes are 5 to 20 (rarely 25) flowered. The pedicels average about equal to the calyx tubes in length, while the calyx teeth average one-fifth longer than the calyx tubes. The pods are loosely coiled in from one-half to two turns, are reticulated, and dark brown in color when mature. The leaflets are oblong lanceolate and very frequently

[a] Martyn. Flora Rustica, 1792, vol. 3, p. 87.

[b] Persoon. Synopsis Plantarum, 1807, vol. 2, p. 356. "*Medicago media*, pedunc. subcorymbosis, flor. pallide cæruleis demum flavescentibus, foliol. cuneato—linearibus retusis apice dentatis, subtus pilosis. * * * In pratis, collibus et ad versuras agror."

[c] Stebler and Volkart, loc. cit.

are either deeply notched or mucronate at the apex. The leaves often show supernumerary leaflets. The stems vary from decumbent to ascending, are slightly woody at the base, and rather strongly inclined to be four angled. (See Pl. I, figs. 2 and 3.) These hybrids occur apparently wherever the two parents have been associated when seed production was possible and in some instances have spread to other sections.[a] These intermediate forms possess the same disadvantages as does the *Medicago falcata*, although to a somewhat less degree. The stems are too prostrate to be mown easily. The seeding habits, while much better than those of *Medicago falcata*, are not equal to ordinary alfalfa, and in any but situations too unfavorable for the growth of ordinary alfalfa they are not to be recommended.

There has always been more or less confusion as to the identity of the many forms, owing in part to their nonstability and also to the readiness with which they intercross with each other, and especially with ordinary alfalfa, and thus approach the ordinary variety more closely in their characters than do the intermediate hybrid forms. The subsequent intercrossing has been mainly with ordinary alfalfa, owing to its very common culture, and this has brought about forms which closely resemble ordinary alfalfa, but which retain much of the hardiness of the yellow-flowered ancestor, while possessing its disadvantages to only a slight degree.

VARIEGATED ALFALFA.

The designation "variegated alfalfa"[b] is intended to comprise the progeny of the intermediate hybrid forms just discussed, which have been recrossed several times with ordinary alfalfa and also among themselves. The mixed hybrid shows in each of its characters some

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[a] Stebler and Volkart, loc. cit.

[b] It is difficult to designate botanically the maze of widely varying forms here called variegated alfalfa. They range from those which are strictly intermediate between *Medicago sativa* and *M. falcata* to forms which so closely resemble *Medicago sativa* as to be optically indistinguishable from the latter. The designation "*Medicago falcata* $\times <$ *Medicago sativa*" would be in accordance with both the American and Vienna codes of botanical nomenclature for a hybrid which resembles the *Medicago sativa* parent more closely than it does the *Medicago falcata*. This, however, does not indicate the repeated recrossing of *M. sativa varia* which has apparently occurred with *M. sativa* as the male parent. The designation "*Medicago falcata* $\times$ (*M. sativa*) ^{n}" would indicate the apparent true relationship of these plants. The group lying between the strictly intermediate forms and *Medicago sativa* has been designated "*Medicago varia pseudo-sativa*" by Rouy and Foucaud in Flore de France, with the following synonymy: *M. sativa β. versicolor* Koch, *M. spuria* Hy., *M. cyclocarpa* $\times$ *sativa* Hy., *M. sativa* $>$ *falcata* R. and F. It is not desired, however, in the present publication to do more than to call attention to the facts as they appear.

relation to both parents, but the characters much more closely approach those of ordinary alfalfa than they do the yellow-flowered species. (See Pl. III, figs. 2, 3, and 4.)

The flowers are predominantly violet, but normally about one-third show the variation in color as described for the intermediate forms. The flowers are borne in racemes of from 5 to 25 flowers each. The peduncles bearing the racemes are normally borne as in ordinary alfalfa, but they sometimes approach the subcorymbose habit referred to in the original description of *Medicago media*. The pedicels are usually about one-third shorter than the calyx tube, while the calyx teeth are about one-fourth longer than the calyx tube. The pods are coiled in from 2 to 4 (rarely ½ to 1) spirals, somewhat looser than in ordinary alfalfa, and are of a darker brown color when mature. The three leaflets are obovate to lanceolate and are frequently deeply notched or mucronate at the apex. The individual plants show a decided tendency to produce leaves with supernumerary leaflets. The stems are ascending, but possess a tendency to lodge (see Pl. II, figs. 1 and 2) and are slightly coarser than the ordinary alfalfa and strongly inclined to be four angled. The present geographical distribution of the different strains of variegated alfalfa has not been entirely worked out, but most of the introductions can be traced to parts of Eurasia where the two parental forms occur and where the conditions are not entirely favorable to the successful production of ordinary alfalfa. The principal introductions have been secured from the Rhenish provinces, Bohemia, and eastward, but usually north of the forty-ninth parallel of latitude.

The handicaps under which the intermediate forms labor—procumbent growth, poor seeding habits, and relatively light yields—have been overcome in these forms by the influence of successive crossing with the ordinary alfalfa. They retain, however, sufficient of the yellow-flowered alfalfa parentage to make a considerable proportion of the individuals decidedly more hardy than the ordinary alfalfa.

The characteristics of variegated alfalfa will be more fully discussed under the heading "Comparison of the different strains of variegated alfalfa and their parents."

STRAINS OF VARIEGATED ALFALFA.

The wide distribution of the yellow-flowered alfalfa in Eurasia has resulted in ordinary alfalfa being brought into contact with it at many places and has thus given rise to many independent sets of hybrids. These different forms as a whole agree rather closely in their botanical characteristics, but differ one from another in the climatic conditions

to which they have been subjected and also in the amount of subsequent recrossing with either or both of the original parental forms. The three most important strains and the only ones which have been given severe tests for hardiness are the Grimm alfalfa, which has been grown successfully in Minnesota since 1858, Canadian alfalfa (in part), and the commercial sand lucern (in part). Several small lots of seed have shown very close botanical relationships to the forms just mentioned and have some direct claims to hardiness on account of the severe climatic conditions characterizing the regions from which the seed has been procured. They have not, as a rule, however, been rigorously tested as yet under field conditions in this country.

COMMERCIAL SAND LUCERN.

The term "commercial sand lucern" is used in the present publication to designate the alfalfa recognized by various seed houses in Europe and America as sand lucern. The necessity for this distinction is occasioned by the fact that the commercial sand lucern of to-day is quite different from the early forms of sand lucern referred to by European writers. The original sand lucern is properly classed with the preceding category of intermediate forms of alfalfa; that is, the first or early generation hybrids between *Medicago sativa* and *Medicago falcata*. The commercial sand lucern has, on the other hand, been so materially modified by repeated crossing with ordinary alfalfa as to be classed in the category of variegated alfalfa. (See Pl. II, fig. 1.) It is necessary to give a brief account of the history of the original sand lucern to indicate the origin of the commercial sand lucern of the present time.

History of the early forms of sand lucern.—There is some confusion in the literature regarding sand lucern, owing apparently to its unstable character when grown for successive generations near either the yellow-flowered alfalfa or the ordinary alfalfa. It may have had its origin in any one or all of three ways: First, the seed of natural hybrids may have been gathered and seeded.[a] Miller describes one instance of its early domestication in England as follows:[b]

> Thomas Le Blanc, esq. of Cavenham in Suffolk, having been struck with the luxuriance of the yellow Medick in the poorest soils, determined to have the seed gathered, in order to cultivate it. Whilst engaged in this pursuit, he happened to find the variegated Medick, and observing it to be more luxuriant even than the yellow, it commanded his attention.
>
> It is less erect, he says, and less succulent than Lucern; but more succulent and much more luxuriant than the yellow Medick. The seed pods partake of the shape of each, being less twisted than those of Lucern, but more so than those of yellow Medick. The flowers are beautifully varied in every shade of blue and greenish

[a] Stebler and Volkart, loc. cit.

[b] Miller. Gardener's and Botanist's Dictionary. 1807.

yellow, and some are almost white. His reasons for preferring it to Lucern are, that it is hardier in bearing cold, that from its habit of branching below the surface of the ground, and the shoots being much more numerous, it is not choaked by natural grasses, and that for the same reason it will not be injured by being fed with sheep, and that it grows spontaneously upon the poorest soils.

In 1783 he began with a single plant, which he transplanted into his garden, the soil of which is a blowing sand. In 1784 he gathered the seed of it, and in April 1785 he sowed with it a bed consisting of five rows, thirty-nine feet long. The plants came up thick and strong: some of them blossomed at the beginning of July in the same year, and measured above two feet in height. Although all the seeds were gathered from one plant, yet the flowers differed very much in colour: some being almost yellow, some almost white, and others purple of various shades. In August the same year he took up the same seedlings, six thousand six hundred in number, and transplanted them. Some of them measured two feet and a half in height. Most of the roots were cut through with the spade; one which was pulled up measured two feet nine inches in length. He likewise dug up a few wild plants, which he divided into a great number of slips, every one of which grew. * * *

The 4th of December the plants were not affected by the frost; at the same time the shoots of Lucern were entirely destroyed. * * *

In June 1789 Le Blanc's Medick was in blossom before the Lucern, and much fuller of flower. Both the transplanted and sown flowered luxuriantly: he saved it for seed, but it produced a very small quantity; in November he dressed it with ashes.

May the 26th 1790, he cut a square yard of Lucern, and an equal measure of the Medick adjoining; the Lucern was tallest, and appeared the larger bundle, but upon weighing them, the Lucern was three pounds three quarters, the Medick four pounds and a quarter. The crop of Medick was very fine, and had the appearance of having been sown broadcast, the intervals being so filled up, that the drills could not be distinguished, whereas the rows of the Lucern were very apparent. * * *

Mr. Young remarks upon this very satisfactory account of the introduction of a new plant into culture, that may bid fair to rival Lucern itself, that Mr. Le Blanc's farm at Cavenham being on a poor blowing sand, he has very happily fixed on a plant which appears to thrive better on such sand than in richer soils. Mr. Young tried it in moist loams, worth 15s. an acre, but never could get the plants to do so well as on the poorest sands.

The second possible origin is that the seed of the wild yellow-flowered alfalfa (*Medicago falcata*) may have been gathered and seeded near plants of ordinary alfalfa when hybridizing would normally take place, producing the intermediate forms.[a] A third possibility is that natural hybrids may have occurred in fields of ordinary alfalfa and that the resulting hybrid forms have been perpetuated in preference to the ordinary alfalfa either by unconscious natural or artificial selection. That the second method, namely, that the original selections were *Medicago falcata* and that they may have formed an important early source, is substantiated by the apparent early impression that sand lucern should show only yellow flowers.[b] Further, the name "Swedish alfalfa" has been applied both to the

[a] Metz & Co. Berichte über Nutzpflanzen. Berlin, 1868, p. 13. Stebler and Volkart, loc. cit.

[b] Metz & Co., loc. cit.

wild yellow-flowered alfalfa and to the hybrid forms between this and the ordinary alfalfa.[a] Stebler and Volkart [b] state that according to Ascherson the seed of the original sand lucern was first gathered on the "barren heights of Eifel." [c] This was presumably before 1841, since the same account states that its culture could not have assumed much importance by that time, since J. Metzgar, in his thorough work on agricultural plants, dated 1841, knew nothing of its culture.

Intermediate alfalfa did not attract particular attention agriculturally until 1842, when its ability to withstand the severe drought of that year in Germany brought it to the attention of agricultural writers.[d] It may have been cultivated first in Sweden,[e] but it could not have much preceded the first trials of it in Germany, since the culture of ordinary alfalfa in Sweden can not with certainty be traced farther back than 1840, when it was seeded at one of the experiment stations.[f] Practically all of the European accounts of the original sand lucern are based upon the showing made by it on the poorer classes of soils, both sand and clay, in France, Germany, and eastward. These accounts have made little or no note of the fact that under cultivation in association with ordinary alfalfa it intercrosses with that and more and more closely assumes the characters of the latter. This passing into forms closely approaching ordinary alfalfa has gone so far that it is exceedingly difficult to obtain through commercial sources even small quantities of the seed of the truly intermediate forms. The different lots of commercial sand lucern imported into this country have never, so far as observed, shown more than a very small percentage of intermediate forms strictly comparable with the original sand lucern. On the other hand, the relationship to both parents is generally indicated in some way on the part of the individual plants, although they quite closely approach ordinary alfalfa in general appearance. Stebler and Volkart [g] state that their tests of commercial sand lucern proved

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[a] Pinckert, F. A. Anleitung zur Cultur und Benutzung des Bastardklees, der Sandluzerne und Esparsette als bodenbereichernde Futterkräuter. 1860.

[b] Loc. cit.

[c] The heights of Eifel are located a few miles west of the Rhine River and about 35 miles south of Koln (Cologne), Germany.

[d] Pinckert, F. A., loc. cit.

[e] Pinckert, F. A., loc. cit. Bisher wurde dieselbe am meisten in Schweden angebaut, ein Beweis, dass sie auch bei uns in den nördlichen Gegenden sicher gedeihen wird. Bei uns sind die meisten Versuche ihres Anbaues in den Rheingegenden gemacht worden, wo sie zuerst von v. Arnstädt in Gr.-Kreutz eingeführt wurde. Dort ist namentlich die Sandluzerne im Grossen auf einzelnen Gütern in der Rheinprovinz und zwar im Kreise Rees angebaut worden, desgleichen hat sie sich auch im Kreise Simmern auf allen Bodenarten gut bewährt.

[f] Kongl. Landtbruks-Akademiens Handlingar och Tidskrift, 1893, p. 292.

[g] Loc. cit.

to be mostly "blue lucern."[a] This opinion as to the cause of the gradual approach of the intermediate hybrid forms to ordinary alfalfa by successive recrossing where the two are grown near together confirms the results of the experiments discussed under the heading "Re-creation of variegated alfalfa," page 33.

It is possible that another important factor in bringing the intermediate forms to forms so closely resembling the ordinary alfalfa is that owing to the higher price of the seed of the original sand lucern it has been adulterated with seed of ordinary alfalfa, which intercrossed with the original sand lucern and thus produced a mongrel progeny with the characters of the ordinary alfalfa predominating. The relatively small amount of sand lucern seed produced in some sections may have led to its being bulked with the seed of ordinary alfalfa, with similar results. The original sand lucern does not at present appear to possess much importance agronomically, as it is practically impossible to obtain the seed commercially even for small experimental plots. Its chief value lies as breeding stock, and it can be readily produced by growing the two parents side by side under conditions which favor the setting of seed. The commercial sand lucern is, on the other hand, of considerable agronomic importance, and it is with this kind of seed almost without exception, rather than with the intermediate forms, that the tests have been carried on under the name of "sand lucern" in this country by private individuals, by the state agricultural experiment stations, and by the United States Department of Agriculture.

Results with sand lucern in America.—It is only within the past two decades that attention has been given to experimenting with sand lucern in the Western Hemisphere. One reason for this is the fact that most of the various experiment stations were not organized before that time. A more potent reason, however, is the handicap of the name under which this variety labored. It was called "sand lucern" from its ability to grow on certain poor sandy soils of Germany, and it has been pointed out that it might equally as well be called "clay lucern."[b] In parts of Europe it has been designated as "hardy alfalfa," and had Europe possessed such large areas of cultivated land requiring a hardy or drought-resistant alfalfa as does our own country it is probable that the value of this form would have been appreciated at a much earlier date. Furthermore, the European accounts have dealt mainly with the original forms of

[a] The term "blue lucern" is sometimes used to designate the alfalfa commonly produced in Germany. As will be pointed out under the heading "German alfalfas," the German-grown alfalfas normally possess a considerable percentage of blue blossoms in addition to the ordinary violet-colored blossoms characteristic of ordinary alfalfa.

[b] Metz & Co. Berichte über Nutzpflanzen, Berlin, 1868, p. 89.

sand lucern, which it was admitted could not compete with ordinary alfalfa under conditions to which ordinary alfalfa is adapted. The disadvantages of the nearly prostrate habit of these intermediate forms were pointed out, together with their rather poor yielding qualities. These handicaps served in the aggregate to retard interest in both the original intermediate form and in the commercial sand lucern. Its exploitation has thus been correspondingly retarded.

Under the name "lucerne rustique" or "hardy alfalfa" the sand lucern, probably the commercial form, was tested in Brazil in the latter years of the nineteenth century.[a] Under the tropical conditions present it was outyielded by the Provence alfalfa, with which it was compared. The yield for the first four of the seven cuttings procurable during the long growing season was at the rate of 6,057 pounds to the acre for the Provence alfalfa as compared with 5,255 pounds for the sand lucern. In Canada, on the other hand, the tests carried out showed the sand lucern to be superior to the ordinary alfalfa.[b]

In the United States, tests of sand lucern have been made at a number of different points. It was grown in 1889 in Delaware[c] and in 1892 near Baton Rouge, La.[d] In the tests made in Delaware it was injured by the leaf-spot (*Pseudopeziza medicaginis*), as was also the ordinary alfalfa. In Louisiana it was choked out by the native grasses.[e] Herbarium material taken at the Mississippi Agricultural Experiment Station in 1892 indicates that it was under test there at that time.[f] In small plot tests commenced in North Carolina in 1891 and reported in 1894, sand lucern succeeded under the unfavorable conditions present somewhat better than did the ordinary alfalfa.[g]

Probably the most noteworthy early trial of commercial sand lucern in this country was made by the Michigan Agricultural Experiment Station commencing in 1897. One-sixth acre of light sandy soil was seeded to the sand lucern and the cured hay weighed during the four succeeding years. The surface soil had for the most part been removed by grading, and the soil on which the seed was

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[a] Boletim do Instituto Agronomico do Estado de São Paulo em Campinas, no. 8, vol. 10. 1899.

[b] Bulletin 46, Central Experimental Farm, Ottawa, Canada. 1904.

[c] Second Annual Report, Delaware Agricultural Experiment Station, 1889, p. 16.

[d] Bulletin 19, second series, Louisiana State Experiment Station. 1892.

[e] This is also usually the fate of ordinary alfalfa seeded under similar conditions in the same section.

[f] The specimen is now deposited in the herbarium of the Michigan Agricultural College.

[g] Bulletin 98, North Carolina Agricultural Experiment Station. 1894. The statement, "Resembles lucern, but plant does not grow so high; flowers mostly yellow," would indicate that it was the intermediate form and not the commercial sand lucern that was under test.

sown was so sandy as to be somewhat drifted by the wind. The calculated yields per acre, based on the yields obtained from the one-sixth acre plot, are given below:

Year.	Cuttings.	Cured hay per acre.
	Number.	*Pounds.*
1898	3	6,800
1899	4	10,580
1900	4	12,310
1901	4	13,839
Total for four years	.....	43,529

The ordinary alfalfa seeded on the station grounds at the same time was so badly winterkilled that it was plowed under. The winter of 1898–9 was especially severe at the Michigan station, and wheat, clover, fruit trees, and other hardy plants were killed. The sand lucern was practically uninjured, although the thermometer registered temperatures as low as −24° F.[a]

The Michigan Agricultural Experiment Station, in another alfalfa variety test started in 1903, compared the merits of sand lucern, Turkestan alfalfa, and alfalfa from Germany with American-grown seed. In the spring of 1905[b] the sand lucern and Turkestan plots were notably better than the others. The American-grown seed was badly winterkilled, while the Turkestan alfalfa maintained an almost perfect stand. The Colorado alfalfa was visibly poorer than the sand lucern and Turkestan alfalfa. The minimum temperatures for the winter of 1904–5 were −18° F. on December 14, 1904, and −16° F. on February 15, 1905. The sand lucern was also

[a] The winterkilling noted in Michigan in 1898–9 appears to have been due quite as much to the unusual conditions as regards precipitation and relatively high temperatures in January as to the actual minimum temperatures. The months of December and January were exceptionally warm. Until January 28 no temperatures were registered below 0° F. On January 28 there commenced a series of minimum temperatures below zero which continued until February 14, with the exception of February 2, 3, and 4. These low temperatures reached their absolute minimum on February 12, when −24° F. was registered. The customary heavy winter snows did not commence until March. The snowfall up to January 13 had been 8.25 inches, distributed over six different days. This was presumably melted, since on January 13 there was 0.65 inch of rain, with a minimum temperature of 36° and a maximum temperature of 40° F. From January 13 until the extremely cold weather above noted set in on January 28 there were but 1.8 inches of snow, distributed over four nonconsecutive dates. It will thus be seen that the lack of snow protection was combined with the preceding relatively warm weather, by which the evil effects of the low temperatures were increased. It is worthy of note that during this same winter the fields of ordinary alfalfa were winterkilled in central Minnesota, while the Grimm alfalfa fields were uninjured. See Annual Report, Minnesota Agricultural Society, 1903.

[b] Bulletin 225, Michigan Agricultural Experiment Station. 1905.

tested at the Michigan Upper Peninsula substation. It gave slightly larger yields than did the German alfalfa, which stood second in rank as to yield in the test of several varieties. Unfortunately, however, the tests were not strictly comparable, owing to variation in the ground and also in the stand secured.

Another series of experiments was inaugurated at the Michigan Agricultural Experiment Station in the spring of 1905 in cooperation with the United States Department of Agriculture. The plantings were made both at the central experiment station grounds and also at the substation of the Upper Peninsula. At the latter place the first series of five varieties was seeded on a plot which had been intensively cultivated so as to be entirely free from quack-grass and weeds. The yields per acre secured in 1906 were as follows:

	Pounds.
Sand lucern (commercial) (variegated)	7,680
Colorado alfalfa (S. P. I. No. 12398)	7,360
New York alfalfa (S. P. I. No. 13291)	6,880
Nebraska alfalfa (S. P. I. No. 12820	7,360
Arizona alfalfa (S. P. I. No. 13437)	6,720

The next series of five varieties was seeded at the same time upon an adjoining plot which had been in buckwheat in 1904. The presence of much volunteer buckwheat made hand weeding necessary to save the alfalfa plants. This may have affected the yields of this series so as to make it not strictly comparable with the figures just presented.

The reported yields are as follows:[a]

	Pounds.
Wyoming alfalfa (S. P. I. No. 13489)	4,480
Minnesota alfalfa (S. P. I. No. 13438)	4,000
Canadian alfalfa (S. P. I. No. 13436) (variegated)	6,080
Northern Montana alfalfa (S. P. I. No. 13237)	4,160
Kansas alfalfa (S. P. I. No. 13440)	2,720

There appears to be no question as to the fact that the sand lucern under test was the commercial form rather than the early intermediate form. In Bulletin 198 of the Michigan Agricultural Experiment Station the following statement is made:

> In appearance and behavior the difference between the sand lucern and alfalfa is so very slight that only an expert botanist could note the botanical characteristics which distinguish each, and a most careful observer could discern wherein one differs from the other.

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[a] Bulletin 198, Michigan State Agricultural Experiment Station: "Sand lucern has the special advantage over alfalfa of being able to withstand the severe winters of Michigan climate, while the alfalfa is very easily killed out. It is said of the alfalfa, too, that it is liable to be crowded out by June grass, sorrel, and other weeds. So far no difficulty of this nature has been noticed with the sand-lucern seedings. It is quite probable that instead of the weeds running out the alfalfa, the alfalfa has been killed during the severe winter and the weeds have simply taken its place."

In another publication[a] it is stated that the distinction between sand lucern and the other varieties (Turkestan, French, and German) is too small to be noticed by the average observer.

A variety test was made by the Wisconsin Agricultural Experiment Station in which sand lucern was compared with two other varieties of alfalfa.[b] The yields of the cured hay per acre were as follows:

	Tons.
Sand lucern	5.6
Ordinary alfalfa	5.7
Turkestan alfalfa	5.0

These plots successfully withstood the winter of 1903–4, which was noted for its severity. The plots of alfalfa were exposed to the elements without a covering of snow during a large portion of the winter. Unfortunately, it was found necessary to discontinue these tests before the results of the succeeding season could be obtained.

The Utah Agricultural Experiment Station made a comparative test under semiarid conditions between sand lucern and other varieties at the Iron County Experimental Farm, where the rainfall from April 1 to July 20, 1906, was 3.20 inches. The Turkestan alfalfa gave 620 pounds of cured hay per acre, as compared with 590 pounds for the sand lucern and 110 pounds for the Utah dry-land strain. On the Juab County Experimental Farm, where the rainfall was heavier, being 18.44 inches from August 1, 1905, to July 31, 1906, and 6.34 inches from April 1 to July 20, 1906, the Utah dry-land alfalfa gave 2,300 pounds for the Utah seed, which had been produced under irrigation, while the Turkestan gave only 1,500 pounds and the sand lucern 2,050 pounds to the acre. It was pointed out that under conditions of extreme drought the sand lucern and Turkestan alfalfas were apparently superior to the other varieties, although it is stated that definite conclusions should not be drawn from the single series of tests.[c]

Results (unpublished in part) secured at the Kansas Agricultural Experiment Station have shown the ordinary alfalfa to give a heavier yield than either the sand lucern or Turkestan alfalfa in comparison with which it was tested.[d] The normal rainfall of Manhattan, Kans., is 32 inches. The following table indicates the results per acre secured from these plots in the area devoted to small plot tests:

Variety.	Yield in 1906.	Yield in 1907.
	Pounds.	*Pounds.*
Sand lucern (variegated)	5,960	5,280
Ordinary alfalfa	7,340	5,720
Turkestan alfalfa	6,840	5,160

[a] Seventeenth Annual Report, Michigan Agricultural Experiment Station, 1904, p. 222.

[b] Bulletin 121, Wisconsin Agricultural Experiment Station. 1905.

[c] Bulletin 100, Utah Agricultural Experiment Station. 1906.

[d] Bulletin 155, Kansas Agricultural Experiment Station, p. 256.

Aside from the apparent slight inferiority of sand lucern as to yields in sections where ordinary alfalfa is specially adapted, it is probable that under such conditions the recognized tendency of the sand lucern to lodge still further reduces the yield of hay actually received from a given area.

The tests made by the United States Department of Agriculture have indicated that in the regular alfalfa-producing sections sand lucern possesses no apparent merit over the ordinary alfalfa, which succeeds so well under the conditions present in such sections. It has, however, proved specially adapted to the semiarid sections and to the States where ordinary alfalfa is apt to winterkill. It has also shown some indications of being better adapted to the soils of the humid Eastern States, where the conditions are somewhat unfavorable to the successful production of ordinary alfalfa. The drought resistance of sand lucern is indicated in the following tabulation of yields of cured hay and seed per acre secured from three varieties of alfalfa sixteen months after seeding, grown on the uplands of western Nebraska, where the normal annual rainfall is about 15 inches. (See Pl. VII, figs. 1 and 2.) The first crop was allowed to stand for seed, which materially reduced the yield of hay which might otherwise have been secured, since two cuttings are ordinarily procured, and in fact considerable growth was made during the latter part of August and throughout September. The figures show, however, the relative behavior of the three varieties for the one cutting, as all were given the same treatment.

Variety.	Cured hay per acre.	Seed per acre.
	Pounds.	*Pounds.*
Sand lucern (variegated) (S. P. I. No. 20457)	1,359	143
Brott's dry-land alfalfa (ordinary) (S. P. I. No. 19566)	1,154	167
Turkestan alfalfa (S. P. I. No. 18751)	908	62

At Pullman, Wash., where the normal annual rainfall is 22.37 inches, a comparative test of alfalfa varieties in which sand lucern is included is under way. The yields of the two cuttings secured during the season of 1907 from plots seeded in the spring of 1905 are as follows:

	Pounds.
Sand lucern (variegated)	7,524
Ordinary alfalfa	7,089
Turkestan alfalfa (S. P. I. No. 14786)	6,066

As an instance of its hardiness and drought resistance the following table indicates the estimated yields of sand lucern secured near Almont, N. Dak., where the normal annual rainfall is about 16.5 inches. The alfalfas experienced temperatures as low as −36° and

−23° F. in the winter of 1906–7 and 1907–8, respectively.[a] The different varieties were seeded in the spring of 1906 and all made an apparently equal showing the first summer. The cooperator, Mr. John de Lang, of Almont, N. Dak., reported that during the winter of 1906–7 none of the sand lucern was killed, while one-fourth of the Turkestan and two-fifths of the Montana-grown ordinary alfalfa were winterkilled. This winterkilling is reflected in the crop of 1907, when the estimated weights of cured hay in pounds per acre were as follows:

	Pounds.
Sand lucern (variegated) (S. P. I. No. 17087)	4,000
Turkestan (S. P. I. No. 14786)	2,667
Turkestan (commercial)	2,000
Ordinary (Montana grown) (S. P. I. No. 17698)	1,600

The yields in 1908 were much nearer equal, as the plants in the thin stand of the two varieties that were partially winterkilled had made almost sufficient growth to overcome the handicaps of the former season.

In tests made at Babb, Mont., alfalfa seed from a number of different sources was sown in the spring of 1906. The following winter a local thermometer registered −43° F. on February 1, −14° F. on March 15, and −10° F. on April 27, with 14 inches of snow.[b] The snowstorms continued several times each week until May 18. Under these trying conditions both the Turkestan alfalfa and the sand lucern are reported by the cooperator, Mr. C. L. Bristol, to have gone through the winter without injury, while the other varieties under test were more or less injured. Of the rest, the stand from seed grown in northern Montana (S. P. I. No. 17698) was best. The alfalfas grown from seed from Spain (S. P. I. No. 17992) and the Argentine Republic (S. P. I. No. 12547) were badly winterkilled.

There is some evidence to show that a number of the variegated alfalfas are better suited than is ordinary alfalfa to withstand the climatic and soil conditions of the northeastern quarter of the United States. Under such conditions, with an annual rainfall of 40 inches or over, the plants are subjected to an excess of moisture. The alternate freezing and thawing of the ground in the early spring is also very injurious to the plants. In the fall of 1904 the then Office of Grass and Forage-Crop Investigations transplanted the plants in several test rows from the Arlington Experimental Farm in Virginia to the experimental grounds of the Maryland Agricultural Experiment Station at College Park, Md. The winter, combined with the late trans-

[a] These figures are based on an average of those recorded at Glen Ullin, N. Dak., 25 miles northwest, and Bismarck, N. Dak., 40 miles northeast, where records are available.

[b] The minimum temperature for the winter of 1907 was —43° F., according to the official thermometer of the United States Weather Bureau.

planting and the rather wet ground, killed all the alfalfa which had been included in the tests except the sand lucern. In a comparative test of six different lots of alfalfas seeded about September 1, 1906, at Glyndon, Md., about 40 miles north of Washington, D. C., the sand lucern showed the best stand in the following spring, although the alfalfa secured from Montana also suffered no apparent winterkilling. The Argentine alfalfa and the ordinary commercial seed, obtained presumably from southern Europe, showed from a half to two-thirds of the plants winterkilled. The Arabian alfalfa was entirely winterkilled. The absolute minimum temperature for the winter of 1906–7 at Fullerton, Md., 18 miles southeast of Glyndon, was −1° F. At the Arlington Experimental Farm a late seeding test was started on October 18, 1907, to determine the relative hardiness of sand lucern, Turkestan alfalfa, and ordinary commercial Utah-grown seed. The plants produced only the cotyledons and the first leaf before their growth was stopped by the low winter temperatures. The following spring, of the ten hills of each that had been seeded five plants of sand lucern and three plants of Turkestan alfalfa remained. None of the plants from the Utah-grown seed survived the winter. The minimum temperature recorded at Washington, D. C., for the winter of 1907–8 was 3° F.

Other points of minor agronomic importance will be discussed under the heading "Comparison of different strains of variegated alfalfa and their parents."

GRIMM ALFALFA.

Grimm alfalfa, so named from its introducer, was first grown in this country in Minnesota in 1858. In 1900 it had gained considerable local importance, at which time Mr. A. B. Lyman, of Excelsior, Minn., called it to the attention of Prof. W. M. Hays, then of the Minnesota Agricultural Experiment Station, who recognized its hardiness and general value for Minnesota conditions.[a] Owing to its hardiness this alfalfa is of great value in sections where ordinary alfalfa winterkills.[b] In addition to its remarkable showing made in Minnesota it has also proved hardy in Nebraska, Montana, North Dakota, South Dakota, and Canada.[c]

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[a] Bulletin 80, Minnesota Agricultural Experiment Station, 1903; Minnesota Press Bulletin 20, 1904.

[b] See Brand, C. J., Science, n. s., vol. 28, pp. 891–892, and Westgate, J. M., Science, n. s., vol. 30, pp. 184–186.

[c] The following extract is taken from Bulletin 101 of the South Dakota Agricultural Experiment Station, 1907, by Prof. W. A. Wheeler:

The Grimm alfalfa has been tested in many parts of the United States as well as Canada, and has shown itself to be one of the hardiest, if not the hardiest, alfalfa under trial either by the state stations or by the United States Department of Agriculture. A plat of this variety was seen by the writer at Indian Head, Saskatchewan, in the summer of 1906, which was being grown in comparison with several others. It

The only objection to Grimm alfalfa as compared with ordinary alfalfa is a slight tendency of the stems to be decumbent, thus causing some lodging when the growth is rank. (See Pl. II, figs. 2 and 3.) This tendency is less pronounced when grown in semiarid regions, where it is also very well adapted. Numerous attempts have been made to establish ordinary alfalfa in parts of Minnesota where Grimm alfalfa is most grown. These as a rule have been comparatively short lived, while the stands of Grimm alfalfa, according to all available definite testimony, have suffered no serious winterkilling in any one winter for at least thirty years, with the exception of February, 1906.[a] (See Pl. IV, figs. 1 and 2.)

In the winter of 1898–99 it is reported that all the fields of common alfalfa seeded in Carver County were winterkilled, whereas there was no loss to the fields of Grimm alfalfa, even where the fourth crop had been severely pastured the previous fall.[b] In February, 1906, however, the early thaws and subsequent formation of ice sheets destroyed parts of many of the Grimm alfalfa fields, especially where the topography of the lands was unfavorable.[c]

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had passed through two winters without winterkilling in the least and was making a very fine growth, while others under trial had, to a large extent, winterkilled. South Dakota No. 162, which is the Grimm acclimated to South Dakota conditions, ranks with the two or three best alfalfas for South Dakota.

[a] Bulletin 80, Minnesota Agricultural Experiment Station, 1903, pp. 157–158; Farm, Stock, and Home, 1905, p. 65; Annual Report, Minnesota State Agricultural Society, 1903, p. 40.

[b] Annual Report, Minnesota State Agricultural Society, 1903, p. 40.

[c] The following signed statement, under date of July 19, 1908, from Mr. Henry Gerdsen, Victoria, Minn., an old neighbor of Mr. Grimm, throws some light on the early characteristics of this strain:

A short time before the civil war broke out, about 1860, I visited Wendelin Grimm's place, which was 4 miles distant from my place. At that time he had quite a field—probably between 2 and 4 acres—of a solid stand of alfalfa, "everlasting clover," as Mr. Grimm called it.

Mr. Grimm sold seed to his neighbors before 1864. He sold some seed to George B. Nelson, who shortly after went as a substitute for John Holtmeier, who was drafted at the last draft of the civil war, about April, 1865. I got my first alfalfa seed from George B. Nelson three or four years after the war.

As long as I knew Mr. W. Grimm, from 1858 or 1859 on to his death in 1890, his alfalfa stands were never noticeably injured by the winter, except in the very low undrained places, where it always winterkills. The seed I got from Mr. Nelson I sowed in 1868 or 1869, and the same patch shows a good stand to-day (1908), the same being about 90 per cent of a perfect stand. As far as I have observed, the Grimm alfalfa has not noticeably increased in hardiness since its introduction into this country. The only serious winterkilling I have ever observed was in February, 1906, when many of the fields were injured, owing to very warm weather followed by rain and snow and subsequent cold, which formed ice sheets over many of the fields.

The following is an extract from a letter received from Mr. A. B. Lyman, of Excelsior, Minn., under date of October 21, 1908:

It [Grimm alfalfa] was a perfect stand up to the spring of 1906, when it showed these bare spots which have since grown up to June-grass. Grimm alfalfa was never injured but once, and that was at this time. We had a very wet fall and lots of rain during early winter. The latter part of February it came off very warm. "Alfalfa started to grow," I have heard many so state. Then it turned very cold after a hot, rainy day and ice formed even on high places that were a little lower than the rest. Grimm alfalfa was injured where the ice stood.

The injury from ice sheets is illustrated in Plate IV, figure 1, which shows the appearance in 1909 of a field seeded in 1901, with a nearly perfect stand over the higher parts of the field, while the stand becomes successively thinner toward the lower places and is entirely destroyed on the low ground. The injury occurred as above indicated in the latter part of the winter of 1905–6. The normal rainfall of St. Paul, Minn., 25 miles northeast of the section where Grimm alfalfa has been successfully produced for more than fifty years, is 29 inches. The absolute minimum temperature since 1873 is −41° F. The average of the absolute minimum temperatures at St. Paul for the ten years from 1893 to 1902 is −23.3° F.

History.—Grimm alfalfa was brought to this country in 1857 by Mr. W. Grimm from Külzheim, a small village near Wertheim, in the province of Baden, Germany. This statement is based on the evidence of Mr. Grimm's son, Mr. Frank Grimm, of Chaska, Minn., who was 9 years of age at the time his father emigrated to this country. A further substantiation is the testimony of several neighbors of Mr. W. Grimm, who obtained their information directly from him.[a] The seed, said to be about 15 pounds, is stated to have been first sown by Mr. Grimm in 1858.

There appears to have been a good deal of discussion by the late Mr. Grimm and his neighbors as to the original source of the seed brought from Wertheim, where it had been grown for some years before Mr. Grimm came to America. As a result of this, more or less credence has been given to the view that it came originally from Norway, Sweden, or Switzerland. Apparently the reason for this belief was the need of an explanation for its hardiness, as the climate of Wertheim is by no means severe. The average of the absolute minimum temperatures at Wurzburg, 20 miles distant, for the ten years from 1893 to 1902, inclusive, is 3.7° F., whereas the average for St. Paul, Minn., for the same years is −23.3° F. It is also possible that the idea of its Swedish origin comes from the fact that sand lucern has been known as Swedish alfalfa, since it had early been raised in that country. It is easy also to confuse Norway with Sweden. This hearsay evidence is of little moment but accounts for the published statements suggesting both Norway and Switzerland as the original source of this strain.[b]

There are two possible explanations to account for the hardiness of Grimm alfalfa. One is that it was ordinary alfalfa when brought to Minnesota and that it has, since its introduction, developed hardi-

[a] The statement made in Minnesota Press Bulletin 20 that Bonn, Germany, was the European source of the Grimm alfalfa is apparently due to confusing Bonn with Baden.

[b] Bulletin 80, Minnesota Agricultural Experiment Station, 1903; Minnesota Press Bulletin 20, 1904; Annual Report, Minnesota State Agricultural Society, 1903, p. 40.

ness by acclimatization.[a] The consensus of opinion, however, among the old neighbors of Mr. Grimm is that it was hardier than ordinary alfalfa from the start and has not noticeably increased in hardiness since its introduction.[b] The second explanation is that the hardiness is due to its possessing a small percentage of the blood of the hardy yellow-flowered alfalfa (*Medicago falcata*) of Europe and Asia.

It is probable that the original group of dilute hybrids contained some plants which were less hardy than others. There were apparently enough hardy individuals to maintain the stands, although, as with any aging alfalfa field, the number of the individual plants became less and less as the plants grew larger. Any gradual elimination by the successive winterkilling would be compensated for by the subsequent increase in the size of the surviving plants. (See Pl. V, fig. 1.) In this way natural selection is probably always at work in sections presenting unfavorable conditions for the crop. The seed from an old field from which the less hardy plants have been gradually eliminated presumably presents better possibilities for producing hardy seed, as not only the mother plants are the hardiest of the original seeding, but the male parentage is also of the same naturally selected stock, unless there be present associated fields of a less hardy strain. There must have been, however, an initial hardiness in a considerable proportion of the early seedings to have enabled the stands to maintain themselves as they did under the severe conditions present. The effect of the Minnesota winters on ordinary alfalfa has usually been to practically ruin the stand within a few years. This is illustrated in Plate V, figure 2, the field shown with a ruined stand of ordinary alfalfa being located within a few miles of the two fields of Grimm alfalfa illustrated in Plate IV, figure 1, and in Plate V, figure 1.

The evidence of the presence of the yellow-flowered blood in the Grimm alfalfa is borne out by the habit of the individual plants, as well as by the structure of the stems, leaves, and flowers, together with the hardiness and drought resistance of the strain itself. In these respects it is different from ordinary alfalfa and agrees with the commercial sand lucern, which is apparently hardier than ordinary alfalfa by reason of the yellow-flowered alfalfa blood in its ancestry. The data tabulated on page 39 show the resemblance between commercial sand lucern and Grimm alfalfa in numerous botanical characteristics and as clearly show their similar botanical differences from ordinary alfalfa.

There are two possible explanations as to how the yellow-flowered blood became introduced into the Grimm alfalfa. One is that it is

[a] Annual Report, Minnesota State Agricultural Society, 1903, p. 40.

[b] Bulletin 80, Minnesota Agricultural Experiment Station; Farm, Stock, and Home, 1905, p. 65.

ordinary alfalfa which has been gradually influenced by wild yellow-flowered alfalfa plants growing in the vicinity of the fields. This mixing has apparently resulted in some degree wherever the ordinary alfalfa has been grown in sections where the yellow-flowered alfalfa occurs wild.

The second explanation is that the hybrid intermediate forms originally known as sand lucern have become repeatedly crossed with ordinary alfalfa, both by having been grown alongside fields of ordinary alfalfa and by having the ordinary seed mixed with that of the old sand lucern. This is presumably what has occurred to most lots of the original intermediate forms of sand lucern which have come to approach ordinary alfalfa somewhat closely in character. By whichever means the Grimm alfalfa came by its yellow-flowered ancestry, the fact remains that there is apparently about one-third as much yellow-flowered blood in the Grimm alfalfa as occurs in the lots of commercial sand lucern which have been under test and observation. However, the Grimm alfalfa has been much more rigorously tested than have any of the importations of the commercial sand lucern or other strains of variegated alfalfa, and until such tests have been made the Grimm alfalfa must necessarily be assigned first place in regard to tested hardiness in Minnesota and the other States where rigorous tests have been made. As a further instance of the hardiness of the Grimm alfalfa it may be stated that in 1901 Mr. C. B. Clarke seeded Grimm, Turkestan, and ordinary alfalfa on his farm near Jamestown, N. Dak. The ordinary alfalfa was so badly winter-killed that it was plowed up. The Turkestan alfalfa was somewhat injured, but it was mown for hay for several years before it was plowed up. The Grimm alfalfa was practically uninjured.

The comparative trials of the principal strains of variegated alfalfa and ordinary alfalfa made during the winter of 1908–9 show the Grimm alfalfa to be the hardiest of all lots under test. While the sand lucern is somewhat less hardy it is much hardier than ordinary alfalfa and apparently contains a considerable proportion of plants which are well adapted to severe winter conditions.

CANADIAN ALFALFA.

The excellent showing as regards hardiness and yield made by certain of the lots of seed procured from Canadian sources and used in the extension and investigational work of the Bureau of Plant Industry[a] led to an examination of the fields from which the commercial seed is secured. It was noted in the sections visited that there were certain fields which differed markedly from the near-by fields of ordinary alfalfa and which upon examination showed the same flower-

[a] S. P. I. Nos. 13436, 18629, and 19896.

color variation and other differences from ordinary alfalfa, as in the case of the commercial sand lucern and Grimm alfalfa. One field, in fact, showed a greater percentage of plants with flower colors of the ordinary violet than has been observed in any of the other fields of hardy alfalfa noted. Unfortunately, it is the practice to bulk the seed from these fields which show the variegated flowers with the seed from the fields of the nonvariegated and presumably ordinary alfalfa. In this way its identity is largely lost and a great dilution of the yellow-flowered ancestor therefore occurs in the progeny. According to local testimony, the seed was secured through French seed houses, but no recognition of its differences from ordinary alfalfa had been noted by those growing it in Canada. The French seed houses handle the commercial sand lucern under the name of "Lucerne rustique,"[a] or hardy alfalfa, and the importations from them may have included one or more consignments of this variety. The same possibilities exist in regard to its European history as were suggested for Grimm alfalfa. Fields said to be 15 years old and still showing a good stand were noted in the vicinity of Silverdale and Welland, Ontario. The principal injury that had occurred to the stands was in fields with low places where the early thaws in February, 1906, resulted in serious damage in such places. (See Pl. IV, fig. 2.) This injury to some of the stands is probably strictly comparable with the similar injury the same winter to the Grimm alfalfa fields in Minnesota. The absolute minimum temperature for the ten years from 1893 to 1902, inclusive, of Welland, Ontario, is −19° F. The average of the annual absolute minimum temperatures for the same period is −10.7° F. The normal annual precipitation is approximately 37 inches.

At Walhalla, N. Dak., in the extreme northern part of the State, the Canadian alfalfa was reported by Mr. C. W. Andrews of that place as surviving the winter of 1906–7 better than the sand lucern or Montana-grown alfalfa.[b] The absolute minimum temperature of Pembina, N. Dak. (30 miles east of Walhalla), for the winter of 1906–7 was −43° F. The normal rainfall is 19.77 inches.

The Canadian alfalfa in the field tests at the Dickinson substation in North Dakota did not prove to be as hardy during the winter of 1908–9 as did the Grimm alfalfa, the sand lucern, or the Turkestan alfalfas. The absolute minimum temperature was −31° F., with practically no snow on the ground.

MISCELLANEOUS LOTS OF VARIEGATED ALFALFA.

In addition to the three recognized commercial strains of alfalfa which have assumed sufficient importance to have received trade

[a] The term "rustique," as here used, is the equivalent of "native" in English.

[b] Canadian alfalfa, S. P. I. No. 13436; sand lucern, S. P. I. No. 17087; Montana-grown ordinary alfalfa, S. P. I. No. 17698.

names there have also appeared other lots which have not been available in sufficient quantities or have been recognized too recently to render extensive tests possible as yet. These alfalfas agree in showing the variegated flowers and as far as they have been tested show themselves to be hardier than the strains of ordinary alfalfa from corresponding sections. The source from which the various lots of seed have been obtained, as a general rule, affords a suggestion as to the probabilities of the hardiness of these strains. Tests are under way to determine the comparative hardiness of these miscellaneous lots.

German alfalfas.—Several lots of alfalfa received from various places in Germany have proved to possess variegated flowers, and preliminary comparative studies indicate other features in common with the variegated alfalfa. All the lots secured from Germany by the Office of Forage-Crop Investigations of the Bureau of Plant Industry have shown the variegated flowers. The introductions made by private individuals and state agricultural experiment stations have not been critically examined, but considerable positive evidence for and no evidence against the relative agronomic superiority of these introductions has come to hand.[a] Among the introductions made by the Bureau of Plant Industry may be mentioned one from the Pfalz region of southern Germany, one from the province of Baden called "Old German" or "Old Frankish blue lucern," and a third from the Grand Duchy of Hesse called the "Eifeler lucern."

Pfalz adjoins the province of Baden, the original source of the Grimm alfalfa. The alfalfa from this region closely resembles both the Grimm alfalfa and the commercial sand lucern in the color of its flowers and its slight tendency to a decumbent growth. No severe test to demonstrate its relative hardiness has as yet been made. Aside from the studies indicated in the tabulations given under the heading "Botanical characteristics," no critical study of this strain has been made. It was secured under S. P. I. No. 13520.

The Eifeler lucern secured from the Grand Duchy of Hesse, Germany, under S. P. I. No. 12748, is interesting from the fact that the "heights of Eifel," located about 200 miles from where this lot was secured, are reported to have been the place where the original sand lucern plants were secured. The botanical characteristics of this strain of variegated alfalfa are indicated in the tabulations just referred to.

The Old German or Old Frankish blue lucern was secured under S. P. I. No. 22467 [b] from Oberschüpf, in the province of Baden, Ger-

[a] Report, Michigan Board of Agriculture, 1907, pp. 361, 364.

[b] See "Seeds and Plants Imported during the Period from January 1 to March 31, 1908," Bulletin 137, Bureau of Plant Industry, U. S. Dept. of Agriculture.

many, and less than 20 miles from the source of the Grimm alfalfa. This appears to be very similar botanically to the Grimm variety as well as to the alfalfa just described from the Pfalz region. The statements by the German Royal Agricultural Society regarding its hardiness and longevity indicate its abilities in this respect.[a]

Russian forms of variegated alfalfa from Simbirsk and Kharkof.—The alfalfas secured from Simbirsk and Kharkof have also proved to possess the variegated flowers and some of the other characteristics of variegated alfalfa. The lots secured from Simbirsk, Russia, are represented under S. P. I. Nos. 13857 and 14496. The two lots of seed from Kharkof, Russia, are represented by S. P. I. Nos. 13858 and 14497. Simbirsk is in latitude 54° 18′ north and longitude 48° 24′ east. The normal rainfall for Simbirsk is 16.3 inches, and the normal absolute annual minimum temperature based on an eleven-year average is −28° F. Kharkof is in latitude 50° north and longitude 36° 12′ east. The normal rainfall is 19.8 inches, and the normal absolute annual minimum temperature based on a nine-year average is −28° F. None of the four lots of seed secured have been extensively tested for hardiness. However, the high latitude, combined with the continental climate with its severe winters, indicates that these alfalfas must necessarily have withstood rather severe climatic conditions. It is also significant, in view of the probable explanation as to the presence of the variegated flowers, to note that *Medicago falcata* has been secured from Kharkof.[b]

Asiatic forms of variegated alfalfa.—The two lots of alfalfa secured from the northern limits of alfalfa-hay production in central Asia have proved to possess a considerable proportion of flowers with other than the ordinary violet color. The most northern lot of Turkestan alfalfa secured by Prof. N. E. Hansen in 1897 is one of these lots just mentioned. It was assigned S. P. I. No. 1151. This particular lot of alfalfa was secured from Kopal, Siberia,[c] and has proved the best of any of the numerous importations of Turkestan

[a] Mitteilungen der Deutschen Landwirtschafts-Gesellschaft, part 4, 1908. A free translation is as follows:

The Old Frankish blue lucern deserves special attention, since it is a lucern that has been cultivated for a long time in south Germany on calcareous soil and grows for a long time without reseeding. Though the qualities of the seed as to size and color, and sometimes, unfortunately, as to germination, are not so good as those of foreign origin and the price is relatively higher, yet this German lucern seems to have a considerable value, for there is an increasing number of complaints that the foreign lucerns do not last long enough without reseeding and that they suffer a great deal, especially in severe winters.

[b] S. P. I. No. 20717. See "Seeds and Plants Imported during the Period from July, 1906, to December 31, 1907," Bulletin 132, Bureau of Plant Industry, U. S. Dept. of Agriculture.

[c] Latitude 45° north, longitude 79° east.

alfalfa tested by the California Agricultural Experiment Station. No yields for an entire season are available, but 9,256 pounds of cured hay were secured in 1908 from two of the four cuttings made at Tulare, Cal., by the California station. It was estimated that a total yield of 8½ tons for the season was secured. The second lot (S. P. I. No. 1159) secured from Kuldja, Chinese Turkestan,[a] about 130 miles southeast from the source of S. P. I. No. 1151, also produces variegated flowers and shows other botanical characteristics of the variegated alfalfa. Neither of these alfalfas has as yet been thoroughly tested for hardiness in this country, but the high latitude, together with the continental climate of the sections from which they were procured, leaves little question as to their hardiness. The normal rainfall based on a three-year average of Kopal, Siberia, is 12 inches. The average of the absolute annual minimum temperatures for ten years is −20° F.

Wheeler alfalfa.—This name is tentatively assigned to a field of 30 acres of variegated alfalfa at Bridgeport, Kans. This particular field was seeded in 1891, and although it has passed through severe winters and has been overflowed at least twice it still shows a perfect stand. The percentage of flowers other than the ordinary violet is less than in most of the other strains here designated as variegated alfalfa. This alfalfa has shown itself to be an especially strong-seeding strain, although in a section too moist for seed crops of ordinary alfalfa except in seasons of light rainfall. This particular field has produced a seed crop during each of the five years ending in 1909. It is rather more upright than the other strains of variegated alfalfa and apparently possesses considerably less of the *Medicago falcata* parentage. Tests during the winter of 1908–9 in the North-Central States show this strain to be somewhat hardier than the Provence alfalfa or the ordinary western-grown seed procured from Colorado and Utah, but it is much less hardy than the other variegated alfalfas and even than the Turkestan alfalfa and the alfalfa from northern Montana. It has proved much superior to the Provence alfalfa from France in the tests made on Long Island.

Baltic alfalfa.—This alfalfa has been so named from the fact that the seed was originally procured from Baltic or Hartford, S. Dak. It was grown for ten years near Renner, S. Dak., with marked success, and thus attracted the attention of Prof. W. A. Wheeler, who was at that time connected with the South Dakota Agricultural Experiment Station. The South Dakota station secured seed from this field for further test and extension and assigned "S. Dak. No. 167" to this strain. It has, according to the published results, proved

[a] Latitude 44° north, longitude 81° east.

to be very hardy and drought resistant under the severe conditions obtaining at Highmore, S. Dak., where the tests have been conducted.[a]

The normal annual rainfall for Highmore is 17.40 inches. The absolute minimum temperatures for 1905, 1906, and 1907 were −36°, −31°, and −27° F., respectively. This strain has proved to give relatively heavy yields of seed. The percentage of blue flowers shown in the tabulation of the flower-color counts is noteworthy.

RE-CREATION OF VARIEGATED ALFALFA.

It appears to be well established in European literature that the intermediate forms of alfalfa, as represented by the original sand lucern, were produced by natural hybridizing between *Medicago falcata*.[b]

In order to verify the statements regarding the natural hybridizing of *Medicago sativa* and *Medicago falcata* and to further determine the effect of growing the intermediate forms associated with the parental forms, experiments along this line were inaugurated in 1907. The real problem was to determine whether or not the intermediate forms approach closer and closer to the ordinary alfalfa as successive generations are grown associated with it. *Medicago falcata* was grown alongside of the ordinary alfalfa and the seed gathered in the autumn. The resulting plants were hybrids, some of which showed a relatively close resemblance to *Medicago falcata*, while others resembled ordinary alfalfa more closely than they did the falcate-podded female parent. One of the plants was as erect as ordinary alfalfa and showed the normal violet color in the flower.

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[a] Wheeler, W. A. Bulletin 101, South Dakota Agricultural Experiment Station, 1907:

A two years' trial of the variety is rather short upon which to draw conclusions. In all our tests, however, both at Highmore and Brookings, this number has shown itself equal to any in quality, hardiness, and seed production. It has not been sown in the selection rows and so has not been put to quite so severe a test for hardiness as No. 162 [Grimm alfalfa], and as there is no record of its having been tested under northern conditions in the past, as has No. 162, it can not be compared in hardiness to the latter number. In seed production it is equal if not superior to No. 162. In quality and the vigor of early spring growth it appears to be equal to any.

[b] Urban, I. Verhandlungen des Botanischen Vereins der Provinz Brandenburg, 1877, vol. 19, p. 125. Urban's experiments showed that when the yellow-flowered alfalfa is grown alongside of the ordinary alfalfa reciprocal hybrids are produced. The hybrid progeny of the crossing of *Medicago falcata* and *Medicago sativa* could not be distinguished from the reciprocal hybrids. The reciprocal prepotency of the pollen of one species over that of the other is indicated by the fact that all of the plants produced from seed gathered from the yellow-flowered plants produced hybrids, while but two of the plants from seed gathered from the ordinary alfalfa failed to show the same intermediate characters of semiprostrateness and flower-color variation.

(See Pl. III, fig. 1.) The fact that the pods of the last-named plant showed but from three-fourths to one turn was the principal indication that the hybrid gave of its yellow-flowered falcate-podded ancestry. (See fig. 1, *B*.)

This hybrid plant in turn was permitted to set seed in association with ordinary alfalfa. The progeny resembled ordinary alfalfa more closely than did the first-generation hybrid, which was its female parent. (See fig. 1, *C*.) The coil of the pods had increased from three-fourths of a turn to one and one-half turns. Another plant showing intermediate characters, including pods with one and one-half turns, was allowed to set seed in association with ordinary alfalfa. With one exception, the progeny showed marked approaches toward ordinary alfalfa. (See fig. 1, *E*.) In fact, herbarium material could with difficulty be distinguished from *Medicago sativa* except for the presence of the variegated flowers, passing successively from purple through blue to some shade of yellow.

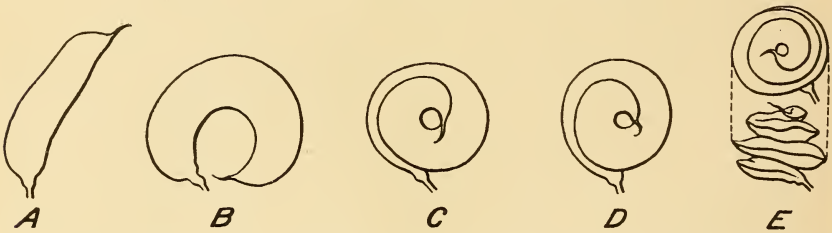

FIG. 1.—Pods of various alfalfas from plants grown near ordinary alfalfa and presumably crossed with it: *A*, *Medicago falcata*; *B*, progeny of plant of *Medicago falcata* shown in *A*; *C*, progeny of plant of *Medicago falcata* shown in *B*; *D*, intermediate alfalfa; *E*, progeny of intermediate alfalfa shown in *D*.

In other experiments performed at the Arlington Experimental Farm open-fertilized violet-flowered plants of the variegated strain of alfalfa have produced progeny showing a much less tendency to vary from the mother plant in flower color than do the plants bearing flowers showing some trace of yellow.

Inbred seed of variegated alfalfa plants with flowers of whatever color normally comes much truer to type than does the open-fertilized seed from the same plants. The experiments indicate that alfalfa is normally open-fertilized and that there is a decided tendency on the part of the intermediate forms to break up, especially when open-fertilized. The descendants of *Medicago falcata* when grown in association with ordinary alfalfa approach closer and closer to ordinary alfalfa at each successive generation. Only a few generations are necessary to produce a stock of plants the majority of which are indistinguishable in appearance from those bearing the variegated flowers to be noted in the various strains of variegated alfalfa. This affords a logical explanation of the observed fact that

the sand lucern of the present day has come to be quite different in appearance and habit from the original forms upon which are based most of the European accounts, both in agronomic and botanical literature. The result has apparently been the same where fields of ordinary alfalfa have been gradually influenced by the neighboring wild plants of *Medicago falcata* or by fields or chance plants of hybrid forms.

In other experiments performed at the Arlington Experimental Farm the prepotency of *Medicago falcata* over the pollen of *Medicago sativa* on open-fertilized plants has not been demonstrated. The progeny of ordinary alfalfa grown associated with *Medicago falcata* has not shown any indication of *Medicago falcata* parentage. However, the associated yellow-flowered plants were very few in number at the time, so that the chances of the pollen from the yellow-flowered species reaching the stigmas of the ordinary alfalfa flowers were relatively small. It should be noted also that examination has shown that the flowers of *Medicago falcata* at the Arlington Experimental Farm produce but a meager supply of pollen as compared with the associated flowers of *Medicago sativa*.

FIG. 2.—Pods of artificial hybrid and parents: *A*, *Medicago falcata*, male parent of plant shown in *B*; *B*, artificial hybrid between the plants shown in *A* and *C*; *C*, *Medicago sativa*, female parent of plant shown in *B*; *D*, pod from inbred seed from female parent of plant shown in *B*.

Artificial hybrids were secured, however, by tripping *Medicago sativa* flowers on the stamen masses of a freshly tripped *Medicago falcata* flower. (See fig. 2.) Since the anthers had not been removed from the flowers of the ordinary alfalfa, it is reasonable to assume that the flowers' own pollen was present, but that it was ineffective in the presence of the pollen from *Medicago falcata*.[a]

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[a] These results are confirmed by letters received from Dr. I. Urban, Under-Director of the Royal Botanical Gardens and Museums, Berlin, Germany, under date of September 23, 1908, in part as follows:

My firm conviction is that sand lucern originally resulted from the intercrossing of *Medicago falcata* and *M. sativa*. The sand lucern now on the market is the product of the crossing of these hybrid plants among themselves and perhaps sometimes with the true lucern. The greater tendency to "lie down" and the greater power of resistance to drought are due to the influence of *M. falcata*.

A free translation of a letter dated August 1, 1908, from Dr. F. G. Stebler, Director of the Seed Control Station, Zürich, Switzerland, is in part as follows:

That the commercial sand lucern has so many violet-flowered and upright forms is due to the fact that with the sand lucern, as well as with the sickle lucern (*Medicago falcata*), cross-pollination is preferred. Pollen of the common lucern is more effective than its own pollen.

COMPARISON OF DIFFERENT STRAINS OF VARIEGATED ALFALFA AND THEIR PARENTS.

A comparative study of the botanical and physiological characters of variegated alfalfa indicates their close relationship and reveals the characters which point to their hybrid origin. The lack of sufficient material has prevented a complete comparative study being made of some of the less well-known strains, but such studies as have been possible indicate rather close relationships.

BOTANICAL CHARACTERISTICS.

In connection with studies as to the botanical characteristics of the different strains of variegated alfalfa observations have been made as to the color of the flowers, size of the floral parts, weight of the seeds, leaf characteristics, and abnormal inflorescences.

VARIATION IN FLOWER COLOR.

Probably the most striking characteristic of the hardy alfalfas is that from 10 to 70 per cent of the plants bear flowers of some other color than violet, among them being blue, dark purple, green, and yellow. These colors are often slightly masked by smoky hues, which increase as the flower becomes older. In addition to this, another phenomenon is that the flowers themselves often show a progressive change in color as they grow older. The buds are almost invariably purple. Some of the flowers will at first be violet, then blue, then bluish green, shading into yellow as the flower becomes aged. In some cases the yellow stage is reached while the flowers are still in their prime; in others the progressive changes may advance no farther than the blue or green, while in still others the ordinary violet may remain dominant throughout the life of the flower.[a]

A possible explanation of this phenomena is that the yellow is present in the flower, but is usually masked by the other colors, which, however, are not so permanent, and as these gradually fade the yellow becomes apparent. Table I shows the results of counts of the flower color of consecutive plants in numerous plots and fields of the different strains of hardy or variegated alfalfa to determine the rela-

[a] In this connection it seems worthy of note that a number of European floras describe this succession of the floral color in the intermediate forms of alfalfa as being in the reverse order from what has been noted by the author in the living specimens examined. As an instance, it may be cited that in discussing sand lucern, which he recognizes as a hybrid between *Medicago falcata* and *Medicago sativa*, Koch states: "Bluten *farbenwechselnd*, zuerst gelb, dann grasgrün, zuletzt bläulich oder violett." (Synopsis der Deutschen und Schweizer Flora, 3d ed., 1892, vol. 1, p. 537.)

tive percentages of plants bearing flowers of the principal color types.[a]

It has been necessary to arrange the color variation into fourteen groups, although nearly fifty different colors or different variations in the colors and rapidity of transition from one color to others in the series have been noted.[b]

TABLE I.—*Results of counts of the various colors found on the flowers of plants of different varieties or strains of variegated and other alfalfas.**

Color of flower.	Medicago falcata.	Unmixed hybrids—M. falcata×M. sativa.	Grimm alfalfa.	Sand lucern.	Canadian alfalfa.	Baltic alfalfa.	Pfalz (German) alfalfa.	Kharkof (Russian) alfalfa.	Simbirsk (Russian) alfalfa.	Wheeler (Kansas) alfalfa.	Algerian (hardy form) alfalfa.	Chinese alfalfa.	Ordinary alfalfa.	Provence Turkestan alfalfa.	Italian Turkestan alfalfa.	Ordinary western-grown alfalfa.
	No.	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*	*No.*
Ordinary violet and lavender	0	6	194	307	314	20	17	43	45	228	8	27	223	108	19	814
Violet, lavender (rarely blue), with dark keels	0	3	47	84	109	10	0	13	6	8	0	6	6	3	0	29
Dark purple	0	0	52	60	62	4	8	10	10	20	3	3	9	6	2	23
Very light lavender	0	0	45	52	28	7	0	8	7	15	1	2	4	0	0	12
Bluish (usually rusty when old)	0	14	179	137	213	27	9	41	9	30	5	8	4	18	4	30
White, tinged with blue or lavender	0	0	4	1	2	2	1	3	2	0	0	0	0	0	0	0
White (ivory)	0	7	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Wine color	0	1	6	16	1	2	0	5	3	10	3	2	3	0	0	0
Reddish lavender	0	6	1	11	3	3	9	3	1	0	0	2	0	0	0	0
Blue-black	0	0	5	3	9	0	2	1	3	1	0	0	0	1	0	0
Blue-green passing into yellow-green	0	6	10	10	4	9	1	6	2	0	0	2	0	0	0	0
Blue or violet, with yellow keels	0	4	13	20	1	3	0	6	3	3	0	1	0	1	0	0
Old flowers cream or yellow	0	38	25	31	15	3	2	11	1	6	2	4	0	1	0	0
Yellow or cream	100	2	1	4	2	0	0	0	0	0	0	2	0	0	0	0
Total number of plants counted	100	87	583	737	764	90	49	150	92	321	22	59	249	138	25	908

* The color of the prime flowers is specified except as noted.

[a] In connection with the explanation advanced for the presence of blue and other colored flowers in hardy alfalfa it may be stated that several introductions of ordinary alfalfa, especially from France and Italy, have shown the presence of some flower-color variation, especially as regards the presence of blue flowers. This is noted in the tabulations here presented. It is not illogical to attribute this phenomenon to the effect of the pollen of scattered wild plants of *Medicago falcata*, which also occur in southern Europe. Any ordinary alfalfa which at any time in its history has been associated with plants of *Medicago falcata* may be expected to show at least slight traces of the mixed ancestry. With no opportunity for elimination of any nonhardy forms that might arise it is hardly probable that such strains would be as hardy as those grown under more severe conditions. In this connection it may be noted that one introduction from Algeria (S. P. I. No. 12803) has shown variegated flowers, as indicated in the tabulation of flower-color variations. This has proved much hardier than the nonvariegated alfalfas from the same section, but has shown some winterkilling under severe tests. The plants from which the seed was secured were said to be much more drought resistant than the ordinary alfalfa.

[b] In making the counts 100 consecutive plants were counted wherever possible. The starting point was taken at random, the usual method being to count consecutive plants in a row, or to count the plants in a rectangle whose center was selected at random, usually by casting some object backward over the head into the field to be examined. One side of the rectangle was extended until the required number of plants had been counted.

The results of the counts of even as many as 100 consecutive plants usually show considerable variation in different fields of the same strain or even in different parts of the same field.

TABLE I.—*Results of counts of the various colors found on the flowers of plants of different varieties or strains of variegated and other alfalfas*—Continued.

APPROXIMATE PERCENTAGES.

Color of flower.	Medicago falcata.	Unmixed hybrids—M. falcata×M. sativa.	Grimm alfalfa.	Sand lucern.	Canadian alfalfa.	Baltic alfalfa.	Pfalz (German) alfalfa.	Kharkof (Russian) alfalfa.	Simbirsk (Russian) alfalfa.	Wheeler (Kansas) alfalfa.	Algerian (hardy form) alfalfa.	Chinese alfalfa.	Ordinary alfalfa.	Provence Turkestan alfalfa.	Italian Turkestan alfalfa.	Ordinary western-grown alfalfa.
	P.ct	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*	*P.ct*
Ordinary violet and lavender	0	6.9	33.3	41.7	41.1	22.2	34.7	28.7	48.9	71.0	36.4	45.7	89.6	78.3	76.0	89.7
Violet, lavender (rarely blue), with dark keels	0	3.4	8.1	11.4	14.3	11.1	0.0	8.7	6.4	2.5	0.0	10.2	2.4	2.2	0.0	3.2
Dark purple	0	0.0	8.9	8.1	8.0	4.5	16.3	6.7	10.9	6.2	13.6	5.1	3.6	4.4	8.0	2.5
Very light lavender	0	0.0	7.7	7.1	3.6	7.8	0.0	5.3	7.5	4.7	4.5	3.4	1.6	0.0	0.0	1.3
Bluish (usually rusty when old)	0	16.1	30.7	18.6	27.9	30.0	18.4	27.3	9.8	9.3	22.8	13.5	1.6	13.0	16.0	3.3
White, tinged with blue or lavender	0	0.0	0.7	0.1	0.3	2.2	2.0	2.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
White (ivory)	0	8.1	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Wine color	0	1.2	1.0	2.2	0.1	2.2	0.0	3.3	3.3	3.1	13.6	3.4	1.2	0.0	0.0	0.0
Reddish lavender	0	6.9	0.2	1.5	0.4	3.3	18.4	2.0	1.1	0.0	0.0	3.4	0.0	0.0	0.0	0.0
Blue-black	0	0.0	0.8	0.4	1.2	0.0	4.1	0.7	3.3	0.3	0.0	0.0	0.0	0.7	0.0	0.0
Blue-green passing into yellow-green	0	6.9	1.7	1.4	0.5	10.0	2.0	4.0	2.2	0.0	0.0	3.4	0.0	0.0	0.0	0.0
Blue or violet, with yellow keels	0	4.6	2.2	2.7	0.1	3.3	0.0	4.0	3.3	0.9	0.0	1.7	0.0	0.7	0.0	0.0
Old flowers cream or yellow	0	43.6	4.3	4.2	2.0	3.3	4.0	7.3	1.1	2.0	9.1	6.8	0.0	0.7	0.0	0.0
Yellow or cream	100	2.3	0.2	0.5	0.3	0.0	0.0	0.0	0.0	0.0	0.0	3.4	0.0	0.0	0.0	0.0

MEASUREMENTS OF FLORAL PARTS OF VARIEGATED ALFALFA.

In order to determine to what extent the floral parts of the different strains of hardy alfalfa are intermediate between the two parents (see fig. 3) a number of measurements were made, the

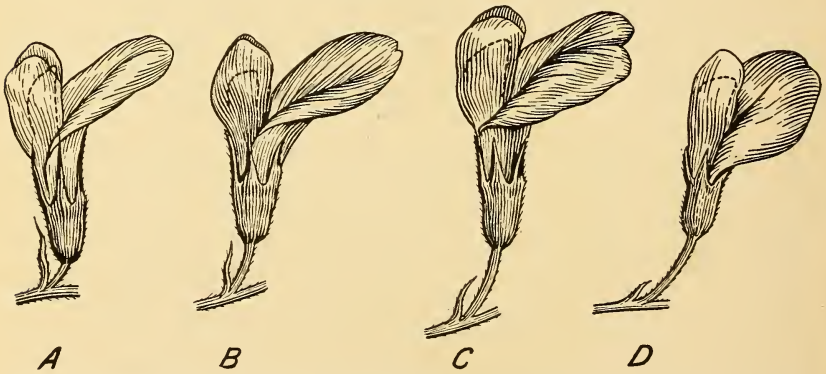

FIG. 3.—Flowers of variegated alfalfa and parental species: *A*, *Medicago sativa;* *B*, Grimm alfalfa; *C*, intermediate form; *D*, *Medicago falcata*.

summaries of which are presented in Table II. Thirty plants of each of the three strains of hardy alfalfa under special study were selected. Five plants each of the six most characteristic colors were included in the selections made from each of the three strains.

Three flowers on each plant were measured. The color types included were ordinary violet, dark purple, blue, very light lavender, and yellow or green. In addition, there was included a series of flowers which showed some shade of yellow appearing in the old flowers. As a basis of comparison, measurements were made of thirty plants of ordinary western-grown alfalfa, six plants of the yellow-flowered falcate-podded alfalfa, and thirteen plants of what are regarded as strictly intermediate forms between the two parents and comparable with the original form of sand lucern.

TABLE II.—*Results of measurements of the floral parts of several varieties or strains of variegated and other alfalfas.*

Variety or strain.	Length of floral bract.	Length of pedicel.	Length of calyx tube.	Length of calyx teeth.	Length of flower.	Width of standard.
	mm.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
Ordinary western-grown alfalfa	1.5	1.4	2.42	3.23	9.9	4.42
Commercial sand lucern (variegated)	1.8	1.7	2.40	3.0	9.2	4.3
Grimm alfalfa (variegated)	1.7	1.6	2.3	3.18	9.4	4.3
Canadian alfalfa (variegated)	1.8	1.6	2.41	3.0	9.2	4.35
Old intermediate form of sand lucern	1.6	2.2	2.21	2.7	9.5	5.0
Yellow-flowered falcate-podded alfalfa	1.9	2.8	2.22	2.6	8.9	4.7

POD CHARACTERS OF VARIEGATED ALFALFA.

With the exception of the striking difference in flower color the shape of the pods of the two parent species is the most distinctive character. In the intermediate forms the pods are usually coiled from one to two times in rather loose spirals. In this way they resemble the falcate-podded parent on the one hand and the ordinary alfalfa with its pods tightly coiled several times on the other. In all of the variegated alfalfas examined there have been found pods more loosely coiled than are the pods of ordinary alfalfa. The predominating pods, however, are indistinguishable from those of the ordinary variety. Occasional plants, however, are to be observed showing pods with one to one and a half coils of the spiral. (See fig. 4.)

SIZE OF SEED OF VARIEGATED ALFALFA.

The number of seeds per pound, calculated from the actual weights of 100 or more seeds, is given in Table III. The samples were taken at random and the seeds counted off consecutively. All the lots were not uniformly cleaned. In some lots all the light seeds were

blown over in the fanning mill. The seeds of the variegated alfalfas are more uneven in size than are the seeds of ordinary alfalfa, and it often happens in cleaning that the small seeds are sifted out with

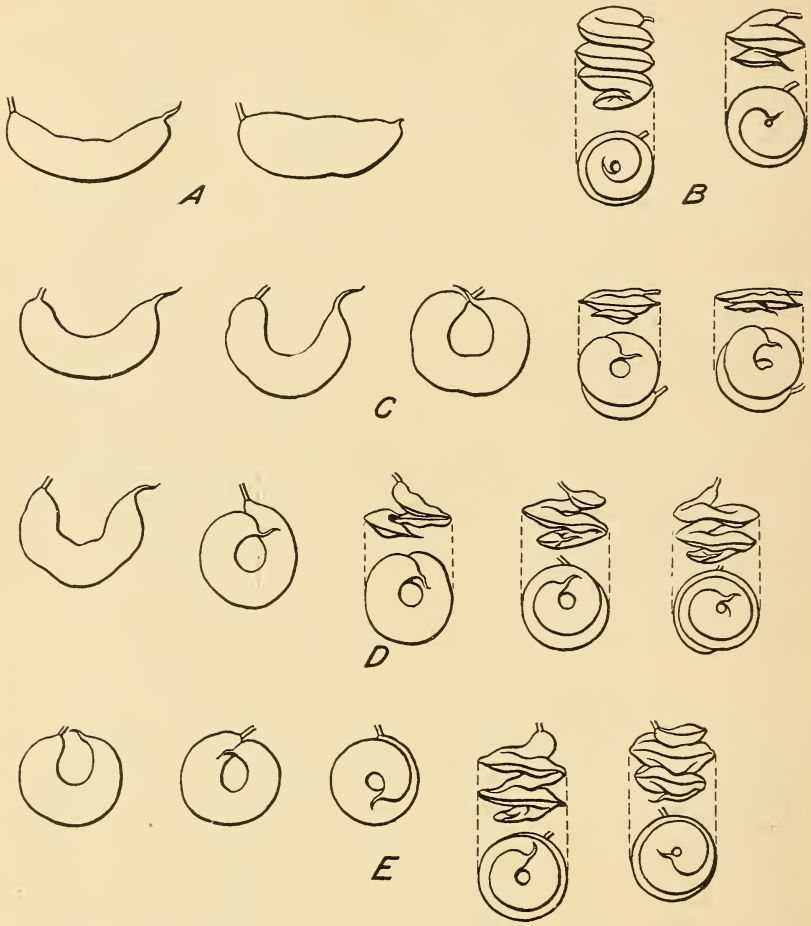

FIG. 4.—Pods of variegated alfalfa and parental species: *A*, *Medicago falcata; B*, *Medicago sativa; C*, intermediate forms of alfalfa; *D*, commercial sand lucern; *E*, Grimm alfalfa. The pods coiled less than once are uncommon in commercial sand lucern and rare in Grimm alfalfa, although the intermediate forms often show them. The fourth and fifth figures in *D* and *E* represent the predominant types in both the commercial sand lucern and the Grimm alfalfa.

weed seeds of about the same size. These sources of error make the results not strictly comparable, but they indicate the tendencies on the part of the different strains of alfalfa.

TABLE III.—*Number of seeds to the pound in various samples of variegated and other alfalfas, with origin of the samples of which counts were made.*

S. P. I. numbers assigned to lots of seed.	Variety or strain and origin of seed.	Seeds to the pound.
		Number.
20719	Medicago falcata from Omsk, Siberia	342,383
20726	Medicago falcata from Samara, Russia (near Siberia)	426,491
20571	Intermediate forms from Upsala, Sweden	272,673
16399	Sand lucern from Pullman, Wash. (grown alongside ordinary alfalfa)	222,767
21217	Sand lucern (variegated) from Europe	248,631
21269	do	250,138
21938	Grimm alfalfa (variegated) from Excelsior, Minn	242,521
21827	Grimm alfalfa (variegated) from Montana	222,568
22467	Old German Frankish lucern (variegated) from Germany	255,487
21247	Canadian alfalfa (variegated) from Ontario	241,489
14497	Russian alfalfa (variegated) from Kharkof	231,515
13857	Russian alfalfa (variegated) from Simbirsk	229,932
12748	Eifeler lucern (variegated) from Germany	232,463
9359	Turkestan alfalfa from Caucasia	228,198
18751	Turkestan alfalfa (commercial)	228,733
12695	Ordinary alfalfa from France (Provence)	214,201
13481	Ordinary alfalfa from Italy	220,068
12549	Ordinary alfalfa from Argentina	174,810
11652	Ordinary alfalfa from Mexico	234,172
23454	Ordinary alfalfa from Montana	244,393

SUMMARY.

	Number of seeds to the pound.
Medicago falcata	384,437
Intermediate alfalfa	272,673
Variegated alfalfas	237,751
Turkestan alfalfas	228,466
Ordinary alfalfas	217,529

LEAF CHARACTERS OF VARIEGATED ALFALFA.

Outline of leaves.—The size and shape of the leaves of both parents, as well as the hybrid forms, vary so much among themselves that no hard and fast description can be made. As a rule, however, the variegated alfalfa shows many of its leaves deeply notched or mucronate at the apex, as is commonly to be observed in *Medicago falcata*. The leaves of ordinary alfalfa are commonly taper pointed and dentate toward the apex, although leaves deeply notched or with mucronate apices are rather frequently noted. This character is of value principally in connection with other characters, as taken in itself it is not conclusive.

Supernumerary leaflets.—A more noticeable characteristic is the presence of supernumerary leaflets on the leaves of many plants of variegated alfalfa. (See fig. 5.) This phenomenon is rather rarely to be observed in ordinary alfalfa, but is very common in the yellow-flowered alfalfas. The occurrence of supernumerary leaflets is more frequently to be observed when the plants are grown isolated and under conditions which tend to produce rapid growth. Table IV, regarding alfalfa grown in rows at the Arlington Experimental Farm, near Washington, D. C., shows that 8 per cent of the plants of ordinary alfalfa occasionally produce supernumerary leaflets, while of

the yellow-flowered alfalfas 50 per cent bear such leaflets. The average for the variegated alfalfas was 26 per cent.[a]

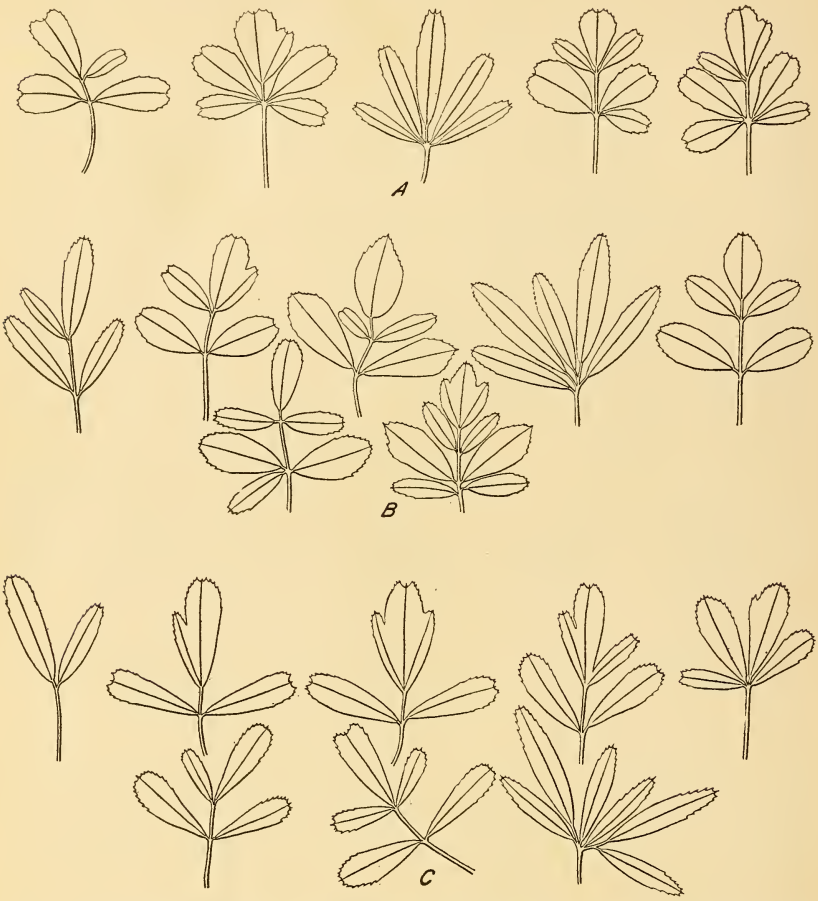

FIG. 5.—Supernumerary leaflets: *A*, *Medicago falcata* (central figure), with two leaves from the intermediate forms on either side; *B*, Grimm alfalfa; *C*, commercial sand lucern.

[a] These counts were, with two exceptions, made on the first crop of the second season's growth of spring-seeded alfalfas in rows 39 inches apart, with the plants rather thin in the row. The Wheeler alfalfa was present at the testing station only in the form of 10 selections from which rooted cuttings had been made. The plants of Old Frankish blue lucern (S. P. I. No. 22467) were not examined until the fall of 1908 in a row which had been seeded the preceding spring. An adjoining row of sand lucern (S. P. I. No. 22418), seeded at the same time, was examined as a basis of comparison. The 20 plants examined were found to show 2 plants possessing supernumerary leaflets.

TABLE IV.—*Supernumerary leaflets on plants of variegated and other alfalfas grown at the Arlington Experimental Farm, near Washington, D. C.*

Variety or strain.	Varieties or strains counted.	Plants examined.	Plants bearing supernumerary leaflets.	
	Number.	*Number.*	*Number.*	*Per cent.*
Yellow-flowered alfalfa	4	18	9	50
Ordinary alfalfa	9	469	36	8
Intermediate alfalfa	2	29	16	55
Grimm alfalfa (variegated; plants in greenhouse)	1	8	4	50
German alfalfa (variegated), S. P. I. No. 13520	1	32	11	34
Baltic alfalfa (variegated), S. P. I. No. 19909	1	20	6	30
Oregon dry-land alfalfa (variegated)	1	4	1	25
Commercial sand lucern (variegated)	3	100	21	21
Chinese Turkestan alfalfa (variegated)	1	42	8	19
Canadian mixed commercial alfalfa (variegated)	2	97	15	15
Wheeler alfalfa (variegated)	1	10	1	10
Turkestan alfalfa	11	477	40	9
Provence alfalfa	1	39	3	8
Arabian alfalfa	3	168	10	6
Andean alfalfa (Peru and Ecuador)	4	164	3	2

Relative abundance of stomata on leaves.—In a preliminary study to determine a possible explanation of the drought resistance of variegated alfalfa it was observed that there was in specimens studied a correlation between the number of stomata per square millimeter and the ability of the plant to resist drought. Counts were also made of both ordinary alfalfa and *Medicago falcata* to determine, if possible, to what extent the character is hereditary or adaptive. Table V indicates the results of the counts of stomata occurring on the under side of the leaves in question:

TABLE V.—*Number of stomata found on the under side of the leaves of plants of variegated and other alfalfas grown at the Arlington Experimental Farm.*

Numbers assigned to plants.	Variety or strain and origin of seed.	Counts made.	Stomata per sq. mm.
		Number.	*Number.*
19534	Medicago falcata from experiment station, Valuiki, Samara Province, Russia.	16	173
20717	Medicago falcata from Kharkof, Russia	5	190
20720	Medicago falcata from Irkutsk, eastern Siberia	4	185
20721	Medicago falcata from Samara Province, Russia	3	193
20725	Medicago falcata from Moscow, Russia (originally from Don Province, in southeastern Russia).	4	185
0686H	Intermediate alfalfa (natural hybrid, Medicago falcata × M. sativa).	1	209
0686C	do	5	246
0686L	do	3	169
0686N	do	2	278
20571	Intermediate alfalfa from Upsula, Sweden	18	253
12991	Grimm alfalfa (variegated) from Alma, Nebr	8	237
16399	Sand lucern (variegated) from Pullman, Wash	1	255
22467	Old German Frankish lucern (variegated) from Germany	6	166
13521	Algerian alfalfa (variegated; relatively hardy)	5	227
Ag. 116	Dry-land alfalfa selection (variegated) from eastern Colorado	5	167
Ag. 42	Dry-land alfalfa selection (variegated) from western Kansas	3	225
Ag. 43	Dry-land alfalfa selection (variegated) from western Kansas	5	202
18827	Ordinary alfalfa, commercial, western grown	17	302
21005	Ordinary alfalfa from south-central Montana	6	286
13437	Ordinary alfalfa from Arizona, grown under irrigation	5	385
17698	Ordinary alfalfa from northern Montana	2	264
19522	Ordinary alfalfa, Provence	4	280
19566	Ordinary alfalfa from Sextorp, Nebr. (Nebraska dry-land alfalfa)	7	234

TABLE V.—*Number of stomata found on the under side of the leaves of plants of variegated and other alfalfas grown at the Arlington Experimental Farm*—Continued.

AVERAGES OF FOUR GROUPS.

Numbers assigned to plants.	Variety or strain and origin of seed.	Counts made.	Stomata per sq. mm.
		Number.	*Number.*
.....	Medicago falcata	32	185
.....	Intermediate alfalfa	29	231
.....	Variegated alfalfa	33	211
.....	Ordinary alfalfa	41	292

STEM CHARACTERS OF VARIEGATED ALFALFA.

The decumbent growth of the stems of most forms of *Medicago falcata* is the most noticeable characteristic, while the upright growth of ordinary alfalfa is an equally salient character. The intermediate forms show such a tendency to this decumbent growth that it materially reduces their agricultural value. Variegated alfalfa, however, shows only a slightly greater tendency to lodge than does the ordinary alfalfa. This handicap should be given consideration in the sections to which ordinary alfalfa is adapted, but in localities where ordinary alfalfa can not be successfully produced this drawback is negligible. In this connection it may be mentioned that commercial sand lucern observed on August 8, 1908, in the testing fields of the Kansas Agricultural Experiment Station had lodged somewhat, whereas the ordinary alfalfa grown alongside was upright. The Grimm has also been found to lodge more than does the ordinary alfalfa. In August, 1907, it was observed on the testing plots of the Nebraska Agricultural Experiment Station, at Lincoln, Nebr., that the Grimm alfalfa had lodged more than any of about thirty other lots under test. This experiment included seed from Turkestan, Europe, and the Western States. A year later the same plots were observed shortly after having been cut. The long decumbent stubbles indicated that the lodging in this strain had again been greater than in any of the other lots under test. At Alma, Nebr., the Grimm alfalfa has lodged rather badly on the bottom lands during the past two years. Plate II, figure 3, shows the lodged condition of the field in 1907. The lodging of this same field in 1908 was so bad that after removing the second crop it was deemed necessary to cut the field again to remove the long decumbent stubbles which it was feared would materially retard the gathering of subsequent crops. The stubble hay thus procured was sufficient to pay for the cost of mowing, raking, and stacking, although the product was entirely devoid of leaves. On the adjoining upland this strain did not lodge, owing to the less rank growth. The stems of variegated alfalfa are somewhat more inclined to be four angled than

are the stems of ordinary alfalfa. Many of the individual plants of *Medicago falcata* show this character. The white lines at the angles of the stems are usually more conspicuous in the cured hay of variegated alfalfa than has been noted in similar stems of ordinary alfalfa.

ABNORMAL INFLORESCENCES OF VARIEGATED ALFALFA.

The common presence of abnormal inflorescences is worthy of special note, as in but very few instances have any of the abnormalities here mentioned been observed in ordinary alfalfa, which if they are present certainly occur much less frequently than in their progeny. (See Pls. VIII and IX.)

Duplication of floral parts.—Flowers with some of their floral parts duplicated have been observed in Grimm alfalfa, commercial sand lucern, and Wheeler alfalfa. This phenomenon usually takes the form of a double keel, though two standards are sometimes present. This is to a certain extent a hereditary character, since the progeny of a single individual of variegated alfalfa has been observed to show a decided tendency to produce flowers with extra-floral parts. One flower with three keels and three standards has been observed in the Wheeler alfalfa.

Crowded inflorescences.—It is a rather common occurrence for the racemes to be subcorymbose toward the top of the plant and to be largely borne there. This phenomenon has been observed in Grimm alfalfa, commercial sand lucern, and Wheeler alfalfa. (See Pl. VIII.) Another tendency observable in the three strains just mentioned is toward the production of whorled racemes, or at least two racemes from the same height and side by side on the main axis. Forked racemes have been observed, and in a few cases the racemes have shown only a small lateral branch with one to several flowers. In some of these cases it has been noted that the subtending bract of the small branch sometimes assumes the form of a narrow-bladed leaflet. These phenomena have been noted in the Grimm alfalfa, sand lucern, Wheeler alfalfa, and also in the variegated alfalfa from Chinese Turkestan. The crowding of the flowers reaches its apparent climax in the compound racemes noted in the Grimm alfalfa and in the Wheeler alfalfa. (See Pl. IX.) In the latter the flowers are borne in sufficiently open clusters to permit the setting of abundant seed crops, although many of the flowers are too crowded to set seed or even to produce normal flowers. The plant observed in the Grimm alfalfa had its flowers crowded so closely together that many of them failed to set seed. Some of the flowers showed duplications of floral parts. A few plants have been observed in the Wheeler alfalfa which have their flowers reduced to minute bracts borne in doubly compound racemes. (See Pl. IX, D.) Occasionally a perfect flower

is to be noted in the small, dense, yellowish clusters of minute aborted flowers. Inbred seed of the compound-racemed alfalfa has produced some plants bearing minute aborted flowers. These have been observed on a plant growing at Rocky Ford, Colo. (Pl. IX, E), and this phenomenon has been reported by Mr. P. K. Blinn, of that place, as having occurred in a locality 50 miles east of Rocky Ford. In neither case has it been possible to determine whether or not these plants were associated with variegated alfalfa, although many of the isolated plants in the vicinity of Rocky Ford and eastward have been observed to possess variegated flowers as well as other characters which make it reasonable to associate these forms with the variegated group of alfalfa. This is apparently the phenomenon noted in *Medicago lupulina* and described by Schmidt as a new species.[a] This is now regarded as merely an abortive form of *Medicago lupulina*. It has also been observed in *Medicago falcata*.[b]

A species of a leaf-spot disease (*Alternaria* sp.) has been observed on the minute bracts which had replaced the floral parts. This, however, was presumably subsequent to the production of the abnormality.

It has occasionally been noted that the subtending floral bract may assume the form of a narrow leaflet. This has been observed in Grimm alfalfa. One plant of *Medicago falcata* has also been observed to show this same phenomenon on its racemes, but with two exceptions this is the only instance where these abnormalities have been observed by the author in either of the parental forms.

PHENOLOGICAL CHARACTERISTICS OF VARIEGATED ALFALFA.

In earliness of starting in spring,[c] as well as in earliness of blooming, the variegated alfalfas appear to exceed the ordinary kinds. This was noticeable in the experimental plots near Washington, D. C. In these plots the hardy alfalfas bloomed about three days in advance of the ordinary alfalfas in the spring of 1908. The earliness of blooming of the Grimm alfalfa and Canadian alfalfa was noted at Fayetteville, N. Y., and Silverdale, Ontario, respectively. At Fayetteville the Grimm alfalfa was being grown in comparison with several other lots of alfalfa, including those from southern Europe, Texas, Utah, Montana, and elsewhere. The Grimm alfalfa was in full bloom on July 12, whereas the other alfalfas were at that time

[a] *Medicago corymbifera* Schmidt, Linnea, 1829, vol. 4, p. 75.

[b] Koch. Synopsis der Deutschen und Schweizer Flora, 1846, p. 1888. In discussing *Medicago lupulina* a statement is made regarding this abnormal form noted occasionally in the species. A translation of the sentence is as follows: "*Medicago corymbifera* is an abnormal formation such as has been observed frequently in *Trifolium pratense* and rarely in *Medicago falcata*."

[c] In the southern half of the United States the variegated alfalfas are normally later in starting than the ordinary variety.

only commencing to bloom. At Silverdale, Ontario, a field of variegated alfalfa was observed in full bloom, whereas a field of ordinary alfalfa alongside it and which had been cut the same day about six weeks previous was not more than one-tenth in bloom. This same phenomenon was also noted at Brookings, S. Dak., in connection with the Simbirsk alfalfa (S. P. I. No. 13857). Near Almont, N. Dak., the commercial sand lucern was observed to be setting seed on July 25, while the associated plots of Turkestan and Montana-grown alfalfa were in bloom but had not commenced to set seed. On October 28, 1908, a series of observations was made of numerous regional lots of alfalfa under test at the Arlington Experimental Farm. The only sorts observed to be setting seed were the South American and the hardy alfalfas. This ability to produce flowers and seed during the entire month of October in the vicinity of Washington is noteworthy, since the mean temperature for the month was 58° F., as compared with 78° for July and 73° F. for August, which are regarded as the best months for seed production. This also affords a possible explanation for the recognized ability of the Canadian and Grimm alfalfas to set seed in Ontario and Minnesota, respectively. There is also apparently greater ability to set seed under humid conditions than is possessed by ordinary alfalfa, and this may lead to the extension of the seed-producing area in the sections which are now regarded as being possessed of too great a rainfall for the successful production of alfalfa seed. As will be noted elsewhere, the heaviest seeding plants at the Arlington Experimental Farm were the selections made from the fields of variegated alfalfa. In this connection reference should also be made to the fact that a field of Wheeler alfalfa at Bridgeport, Kans., has produced successful crops of seed during each of the five years from 1905 to 1909, although none of the years was characterized by the extremes of drought usually considered desirable for successful seed crops of ordinary alfalfa.

PHYSIOLOGICAL CHARACTERISTICS OF VARIEGATED ALFALFA.

CHEMICAL COMPOSITION OF VARIEGATED ALFALFA.

Table VI shows the composition of several different strains of hardy alfalfa, as well as that of the parental forms. The samples were taken at or near the period of early bloom. The samples taken at the Arlington Experimental Farm were from the first crop after sowing. Of these S. P. I. Nos. 21247, 21735, 21827, 22416, and 22467 were taken in 1908, and the chemical composition calculated to a water-free basis. The rest were taken in 1907 and are not calculated to a water-free basis.

TABLE VI.—*Chemical composition of several varieties or strains of variegated and other alfalfas.*[a]

S. P. I. number of sample.	Variety or strain.	Locality where sample was obtained.	Moisture.	Ether extract.	Ash.	Crude fiber.	Crude protein.	Nitrogen-free extract.
19534	Medicago falcata	Arlington Experimental Farm	5.13	3.84	13.21	17.37	18.88	41.57
20571	Intermediate	do	6.95	2.75	11.20	19.95	18.69	40.46
18470	Commercial sand lucern (variegated)	do	5.71	2.72	12.18	19.28	19.69	40.42
16399	do	do	5.90	2.24	13.74	18.97	19.63	39.52
12991	Grimm alfalfa (variegated)	Alma, Nebr. (lowland)	5.36	2.08	10.31	28.30	20.19	33.76
Do	do	Alma, Nebr. (upland)	5.89	2.41	11.29	22.87	20.63	36.91
21735	Grimm alfalfa (variegated), Nebraska grown	Arlington Experimental Farm		2.87	13.42	23.51	18.53	38.71
21827	Grimm alfalfa (variegated), Montana grown	do		2.92	11.05	23.52	20.14	39.15
22467	Old Frankish lucern (variegated)	do		2.99	14.39	20.19	20.36	38.81
19969	Baltic alfalfa (variegated)	do	6.08	2.46	12.75	20.66	19.31	38.74
13520	German (Pfalz) alfalfa (variegated)	do	6.05	2.31	15.93	18.76	19.31	37.64
18629	Canadian alfalfa (variegated)	do	5.10	2.74	14.03	18.19	19.56	40.38
21247	do	do		2.97	10.29	25.64	19.17	38.86
19508	Wheeler alfalfa (variegated)	Bridgeport, Kans	5.45	2.00	11.10	17.74	19.13	44.58
1159	Turkestan alfalfa (variegated)	Arlington Experimental Farm	5.46	2.18	23.35	17.59	17.81	33.61
9450	Turkestan alfalfa	do	4.97	2.22	19.57	20.65	18.13	34.46
18751	do	do	5.02	2.77	10.68	20.06	19.06	42.41
Do	do	Chico, Cal	6.28	2.60	11.86	23.96	15.94	39.36
19522	Provence alfalfa	do	6.00	2.15	11.42	25.94	16.25	38.24
22416	do	Arlington Experimental Farm		3.07	11.76	22.60	18.61	40.98
17698	Ordinary alfalfa, Montana grown	Chico, Cal	6.17	2.00	14.84	23.46	17.81	35.72
18827	Ordinary alfalfa	do	5.98	2.07	14.18	24.12	17.50	36.15
Commercial	do	Mecca, Cal	5.96	2.09	11.29	24.75	17.81	38.10
Do	do	Mesilla Park, N. Mex	5.64	2.36	9.99	22.96	16.63	42.42

[a] Analyses made by the Bureau of Chemistry.

COLD AND DROUGHT RESISTANCE OF VARIEGATED ALFALFA.

In addition to the variegated strains of alfalfa being hardier than corresponding strains of ordinary alfalfa, it has also been observed that the variegated alfalfas are usually somewhat more drought resistant than the ordinary variety. The apparent correlation between hardiness and drought resistance in alfalfa has never received an entirely satisfactory explanation. The fact that the hardy drought-resistant yellow-flowered alfalfa constitutes a small percentage of the parentage of these variegated strains suggests the origin of these characteristics. It is possible that the smaller number of stomata observed in both the *Medicago falcata* and the variegated alfalfa as shown in Table V may offer a partial explanation for the drought resistance, but it is difficult to see how this would materially affect the hardiness of the strains unless the growth be rendered less succulent during the periods of relative high winter temperatures which sometimes occur. The Grimm alfalfa, sand lucern, and Baltic alfalfa have all proved relatively drought resistant. In the tests referred to in discussing the respective strains, the Grimm alfalfa has proved drought resistant in North Dakota, South Dakota, and Nebraska. The sand lucern has shown itself to be drought resistant in North Dakota, Montana, Nebraska, eastern Colorado, Utah, and eastern Washington. (See Pl. VII, figs. 1 and 2.) The Baltic alfalfa has proved drought resistant at Highmore, S. Dak.

Table VII indicates the weights of hay reported to have been produced without irrigation by Mr. Paris Gibson, of Great Falls, Mont., in 1908. Each plot was 1 acre in extent and the entire product was weighed. The hay was weighed when in the usual condition for stacking and was not entirely dry.

TABLE VII.— *Yield of hay of several varieties and strains of variegated and other alfalfas, Great Falls, Mont., 1908.*

S. P. I. number.	Variety or strain.	Yield per acre.
		Pounds.
19896	Canadian alfalfa (variegated)	7,505
20457	Sand lucern (variegated)	6,425
20844	Turkestan alfalfa	5,490
19508	Wheeler alfalfa (variegated)	5,430
19566	Nebraska dry-land alfalfa	4,700

The normal rainfall at Great Falls, Mont., is about 14 inches.

In the spring of 1908 a number of cooperative tests with several strains of alfalfa, including the Grimm alfalfa and commercial sand lucern, were inaugurated in cooperation with the state experiment stations of South Dakota, North Dakota, Minnesota, and Wisconsin.

In the majority of these tests where there were any marked differences the Grimm alfalfa proved hardier than any other of the strains under test. In a number of instances all varieties winterkilled. In but one case was the winterkilling in the plots of sand lucern and Grimm alfalfa such as to necessitate the reseeding of the former without reseeding the latter. The actual percentages of winter mortality of a number of these plots in different States were obtained by comparing the number of surviving plants with the number of nonsurviving plants in a typical square yard in the spring of 1909. The average of all tests where actual counts were made showed that 19 per cent of the counted plants of the Grimm alfalfa winterkilled, as compared with 39 per cent for the sand lucern. The average winterkilling of the different importations of the sand lucerns varied from 9 per cent for one commercial strain, the winterkilling percentage of which was obtained only at Dickinson, N. Dak., to 41 per cent for one introduction (S. P. I. No. 21269), which was presumably adulterated with ordinary alfalfa. In this connection it should be noted that there is always a gradual reduction in the number of plants actually present from season to season in any alfalfa field as the field becomes older. Not all of the winter mortality is due to the actual freezing out of the plants, as considerable reductions of stands are to be observed in alfalfa fields in the southern part of the United States.[a]

The average calculated weight of hay per acre for the first cutting of all tests where yields were secured from adjoining plots of Grimm alfalfa and sand lucern was 2,266 pounds for the commercial sand lucern, as compared with 2,206 pounds for the Grimm alfalfa.

At Dickinson, N. Dak., the North Dakota substation made a comparative test of a number of different alfalfas which were drilled in during the spring of 1908. These alfalfas experienced a winter temperature as low as −31° F. with little or no snow on the ground during the winter of 1908–9. (See Pl. VI, figs. 1 and 2.) The percentage of winterkilling as calculated from the count of the dead and living plants in the spring of 1909, together with the weight of hay secured from the first cutting from plots ranging from one-fourth to one-half acre, is indicated in Table VIII.[b]

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[a] A full stand of alfalfa at the end of the first season usually shows from 20 to 50 plants per square foot, while 8 plants per square foot will present a good stand during the second season of growth. If there are 4 plants per square foot uniformly over the field during the third season of growth, the stand will appear perfect. It is thus evident that a relatively small percentage of hardy plants in a strain may enable the stand to prove a success for a series of years and still lose a considerable percentage of its plants during the first few winters.

[b] This cooperative experiment was inaugurated by Prof. L. A. Waldron, superintendent of the substation at Dickinson, N. Dak., and the data were obtained by Mr. C. H. Clark, under the direction of Mr. O. J. Grace, acting superintendent.

TABLE VIII.—*Percentage of plants of variegated and ordinary alfalfas winterkilled at Dickinson, N. Dak., in 1908–9, with yield of hay in first cutting of crop thereafter.*

Variety or strain.	Winter-killed plants.	Yield of hay per acre.
	Per cent.	*Pounds.*
Grimm alfalfa (variegated)	3	1,411
Sand lucern (variegated)	20	1,826
Turkestan alfalfa	21	1,179
Canadian alfalfa (variegated)	27	538
Utah alfalfa	39	1,173

In a number of instances in North Dakota stands of red clover winterkilled on farms where the variety tests of Grimm alfalfa, sand lucern, and Turkestan alfalfa went through the winter without serious injury.

IMPORTANCE OF VARIEGATED ALFALFA FOR BREEDING AND SELECTION WORK.

In any field of variegated alfalfa there are present numerous forms which have apparently resulted from the splitting of the mixed or multiple hybrids. These widely varying forms constitute an excellent basis for the selection of promising individuals. Futhermore, most of the important strains of variegated alfalfa have been produced under rather severe conditions of climate and soil. In this way the nonhardy individuals have been weeded out. As a specific instance of the possibilities of selection in fields of variegated alfalfa, it may be mentioned that the most promising selections for seed and hay producing qualities made by the United States Department of Agriculture have been secured from fields and plots of variegated alfalfa.

In propagating the selections made from fields of variegated alfalfa it has been observed that inbred seed comes reasonably true to type. Outbred or open-pollinated seed, however, breaks up to a considerably greater extent than does inbred seed. It is unsafe to generalize on the comparatively few preliminary experiments which have been possible up to this time, but the indications are that any really desirable character may be considered to be inheritable to a large degree. A heavily seeding plant usually produces a heavy-seeding progeny. It has been noted, however, where the plant has been crossed with pollen from inferior individuals that the seed-producing power has been somewhat reduced. The plants from the inbred seed, however, have little variation from the parent in their seed-producing ability. It is an open question, however, whether it will ever be desirable except in special instances to breed narrow types of alfalfa. The self-bred plants in some instances have

not appeared to be quite so vigorous as the open-fertilized progeny from the same mother plant, and continued inbreeding may be found to be so detrimental to the vigor of the offspring as to make it impracticable to continue this operation indefinitely.

On the other hand, with numerous types at hand in a given strain there will be a wider range of adaptability to diverse conditions, the intercrossing will serve to maintain the vigor of the plants, and the diversity of habit and characteristics will enable enough plants to survive under a special set of conditions to furnish a satisfactory stand after the adapted forms have perished. The continued intercrossing among the mixed hybrids will induce further variation which will form a desirable basis for either natural or artificial selection. The diversity of soil and climatic conditions which the alfalfa in this country is called upon to withstand calls for strains adapted to as wide a range of severe conditions as possible.[a]

METHODS OF BREEDING NARROW TYPES OF VARIEGATED ALFALFA.

When it is considered desirable to establish narrow types of alfalfa adapted to a particular set of conditions or for a special purpose the hardy alfalfa group constitutes an excellent basis for the preliminary selections, owing to the variation in forms already present. These alfalfas being a mixed race will probably withstand close breeding better than will ordinary alfalfa.

In establishing a strain from a single individual, self-fertilization is necessary.[b] It is usually desirable at first to propagate the mother plant vegetatively by cuttings to secure abundant stock for seed production and to guard against the possible loss of the mother plant.[c]

The necessary inbreeding can best be done by hand, and while the effects of continued in-and-in breeding have not been worked out as yet this process can at least be continued until the vigor of the progeny is seen to be affected, when it can be cross-pollinated with other individuals approaching the desired type. To prevent cross-breeding in connection with the inbred or control-bred plants isolation of some kind is necessary. This is best accomplished on a small scale by inclosing the stalk in a pouch made of mosquito netting, gauze, or perforated paper. (See Pl. III, fig. 4.) On a slightly larger scale it is practicable to use a screened cage to keep out the insects. When,

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[a] Shull, George H. The Composition of a Field of Maize. Proceedings, American Breeders' Association, vol. 4, 1908, pp. 296–301.

[b] Westgate, J. M. A Method of Establishing a Strain of Alfalfa from a Single Individual. Proceedings, American Breeders' Association, vol. 2, 1906.

[c] Westgate, J. M., and Oliver, G. W. The Application of Vegetative Propagation to Leguminous Forage Plants. Bulletin 102, pt. 4, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1907.

however, the work is to be done on an even more extensive scale and many plants used, geographical isolation is advisable. The plot of rooted cuttings of the selected plant should be grown as far as possible from other fields of alfalfa.

It has been found necessary in nature that the explosive mechanism in the alfalfa flower be tripped or exploded in order that seed be set.[a] To release this explosive mechanism it is necessary to apply pressure to the keel. This can be done with any hard object. When several plants are to be worked the method of pinching the entire raceme, as suggested by Roberts and Freeman, can be used to advantage.[b] If, however, the work is to be done on an extended scale it is suggested that a more rapid method be used. The plant should be grasped with the hand at the base and successive pressure or strokes exerted at intervals toward the top.[c] By this method it is possible to work ten plants a minute. The successive pressures will trip a majority of the flowers, while a second working of the plants will trip most of the remaining untripped flowers.[d]

When large numbers of cuttings are grown isolated from other alfalfa fields the possible effect of insects carrying pollen from distant fields can be largely overcome by keeping the flowers artificially tripped by working them each morning during the blooming period. It does not appear probable that the insects which accomplish the natural tripping exert any effect on the stigma of the flower after it has once been tripped by other agencies.

If, however, it is desired to produce in quantities cross-bred seed of known male parentage, rows of cuttings of the selected parents can be alternated and the insects allowed to bring about cross-pollination. The relative potency of the pollen of other plants over that of the plant's own pollen on its stigma has not been fully worked out, but the results indicate that there is at least a slight degree of prepotency on the part of the pollen of the other plant, and this, if true, will

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[a] Burkill, I. H. On the Fertilization of Some Species of Medicago L. in England. Proceedings, Cambridge Philosophical Society, 1894. See also Brand, Charles J., and Westgate, J. M., "Alfalfa in Cultivated Rows for Seed Production in Semiarid Regions," Circular 24, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909.

[b] Methods of Breeding Alfalfa. Bulletin 151, Kansas Agricultural Experiment Station.

[c] Westgate, J. M. Methods of Breeding Alfalfa. Proceedings, American Breeders' Association, vol. 5, 1909.

[d] In an experiment performed at the Arlington Experimental Farm, near Washington, D. C., this method of artificial tripping, in addition to the normal visitation of insects, was found to effect an increase of 25½ per cent in the production of pods over that of adjoining rows of sister plants which had been produced from cuttings from the same individual but which were tripped only by natural agencies, presumably insect visitors.

cause the majority of the seeds produced to be cross-bred. The crossing of each individual flower by hand is such a tedious process as to be impracticable where any but a very few seeds are desired.[a]

OPTIMUM PROPORTION OF MEDICAGO FALCATA IN VARIEGATED ALFALFA.

It has not yet been determined what is the best relative proportion of the yellow-flowered alfalfa in the ancestry of hardy alfalfa for any specific purpose, as, for instance, for drought resistance. This is a very important question, since it is possible to vary to a certain degree the relative proportions of the two species in the hybrid progeny. The agronomic disadvantages of the forms possessing equal proportions of the two species in their ancestry as compared with the forms which possess probably from 5 to 10 per cent of *Medicago falcata* in their ancestry indicate that the latter proportion is somewhat near the proper quantity. The experiments referred to under the head "Re-creation of variegated alfalfa" are being continued with the idea of determining the agronomic as well as the botanical characteristics of the crosses as the proportion of ordinary alfalfa in their ancestry is increased. The reciprocal prepotency of the pollen of the two species makes it appear probable that a single row or a few scattered plants of *Medicago falcata* will affect a relatively large number of the more numerous individuals of ordinary alfalfa. In this way a relatively small amount of the less common yellow-flowered alfalfa can be made to serve as a basis for comparatively large amounts of hybrid progeny.

Experiments are also under way to determine to what extent the amount of variation in flower color is correlated with the hardiness of the different strains in question. It is being taken as a working hypothesis that the percentage of flowers of other color than the ordinary violet is an index to the percentage of the yellow-flowered alfalfa in the ancestry of a given strain. It may also prove an index to its relative hardiness. It must not be considered, however, that these hypotheses do more than indicate what selections should be made for the actual experimental trials of the different lots. The crucial test is the relative ability of the different strains to withstand unfavorable conditions of soil and climate, and these can only be determined definitely by actual tests of the different strains under each given set of conditions. It is thought, however, that the observed correlation of the flower-color variation in the fields of known hardiness may be valuable in selecting other strains for severe tests as to hardiness and general adaptability to unfavorable conditions.

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[a] Oliver, G. W. New Methods of Plant Breeding. Bulletin 167, Bureau of Plant Industry, U. S. Dept. of Agriculture. 1910.

COMMERCIAL ASPECTS OF THE HARDY-ALFALFA PROBLEM.

The demand for alfalfa adapted to conditions too severe for the successful production of ordinary alfalfa will probably always exceed the supply. It is important, therefore, that every possible source of alfalfas that are even suspected of being hardy be investigated to make possible the maximum seed-bearing acreage of this group of alfalfas. Until the hardy character of any lot of variegated alfalfa is appreciated the seed will be bulked with that of ordinary alfalfa and in this way become lost to those who stand most in need of such a product. On the other hand, there will always be a temptation on the part of seedsmen and others to adulterate the seed of any hardy alfalfa with seed of the less hardy varieties. It would be a most desirable state of affairs if arrangements could be made whereby the grower of any hardy alfalfa would market his own alfalfa seed in sealed bags of a certain minimum weight and make sales with a guarantee as to the seed being true to name. Tests are under way to determine whether there are any noteworthy exceptions to the apparent rule that all variegated alfalfas are comparatively hardy and drought resistant, and until the results of such tests are available the seed of any of the variegated and presumably relatively hardy alfalfas which have not been fully tested should be experimented with upon a small scale until their value for a particular set of conditions is demonstrated.

It is important that hardy alfalfa seed be grown under as severe conditions as will permit of profitable seed production. The variability of the alfalfa plant makes possible the selection and establishment of hardy strains possessing other desirable characteristics. For this reason it is very desirable that the practice of growing and selling seed from pedigreed strains be encouraged in every possible way.

The supply of the Grimm alfalfa and even of the Canadian alfalfa will for years be probably far short of the demand. The source of the seed of these alfalfas can be traced, as the location of the fields is known, and in addition the seed has usually been free from noxious weeds. In but few instances has attempted fraud been noted. The utilization of imported commercial sand lucern in this country is open to some dangers which should be given due consideration. In the first place, the seed is apt to contain seed of noxious weeds, such as buckhorn or English plantain (*Plantago lanceolata*). In the second place, the seed can not be readily traced in its origin and is open to the danger of having been adulterated with seed of ordinary alfalfa. These handicaps can be largely overcome by growing carefully selected seed of this strain in the most northerly alfalfa seed-producing sections of this country and Canada, so that any non-

hardy individuals present in the strain will be speedily eliminated. This seed can then be handled on the same basis as the Grimm and Canadian strains, which are already being grown for seed in this country.

CONCLUSIONS.

The studies of the somewhat isolated instances of specially hardy alfalfa fields have shown that these relatively hardy strains agree quite closely among themselves in their botanical characters and differ noticeably in a number of characters from the ordinary western-grown alfalfa.

The investigations recorded in this bulletin have indicated that the primary explanation of the hardiness of these strains is that they possess a small percentage of the blood of *Medicago falcata* in their ancestry. The hardiness of *M. falcata*, which occurs wild in Eurasia, is attested by its natural growth on the dry, cold steppes of Siberia, far north of the range of ordinary alfalfa (*M. sativa*). In both botanical and agronomic characters these relatively hardy alfalfas show slight but recognizable departures from the corresponding characters of *M. sativa* toward those of *M. falcata*. Subsequent natural selection or selective acclimatization must still be assigned at least a supplemental rôle in the development of the hardiness of the strains, since those lots which have been called upon to undergo severe conditions usually contain a greater proportion of hardy plants than those which have never been subjected to climatic environment so unfavorable as to eliminate the nonresistant forms.

The preliminary comparative field tests of the different variegated alfalfas are of too short a duration to make definite conclusions possible as to their relative value. The tests indicate, however, that under very severe conditions the sand lucern, while much hardier than the ordinary alfalfa, is somewhat less hardy than the Grimm alfalfa, which has been successfully produced in Minnesota for fifty years. The initial seeding of any of the variegated alfalfas should be made on a rather small scale in sections new to these alfalfas. It is suggested that Grimm alfalfa be given the preference in sections presenting very severe winter conditions and that other strains, such as sand lucern and Canadian alfalfa, be more largely utilized in sections where the climate is somewhat less severe, but where it is still too trying for ordinary alfalfa. In regions calling for the hardiest alfalfa such strains as sand lucern should be used as a substitute for Grimm alfalfa when the seed of the latter is not available.

The great variation present among the individuals of the different strains of variegated alfalfa makes them especially promising for breeding and selection work in connection with the further development of improved strains of alfalfa.

DESCRIPTION OF PLATES.

PLATE I. Fig. 1.—A mature plant of *Medicago falcata*, showing nearly prostrate habit. Fig. 2.—A single plant of intermediate alfalfa, showing decumbent stems. Fig. 3.—Plants of intermediate alfalfa in a nursery row, showing partially prostrate habit. Fig. 4.—A single plant of ordinary alfalfa, showing upright habit.

PLATE II. Fig. 1.—A single plant of commercial sand lucern with the stems slightly decumbent. Fig. 2.—A single plant of Grimm alfalfa, showing a slight tendency toward prostratism. Fig. 3.—Field of Grimm alfalfa near Alma, Nebr., showing lodging. An adjoining field of the same strain of alfalfa on ground 30 feet higher showed much less lodging.

PLATE III. Fig. 1.—A natural hybrid alfalfa plant. This was grown from seed procured from a plant of falcate-podded alfalfa which was grown associated with ordinary alfalfa. The pods showing but one coil are illustrated in text figure 1, *B*. Fig. 2.—A single plant of Grimm alfalfa, showing fairly upright growth and great leafiness. Fig. 3.—Two Grimm alfalfa plants of widely divergent types. These same types are to be observed in other strains of variegated alfalfa, such as commercial sand lucern. Fig. 4.—A single plant of an upright selection of variegated alfalfa. Selected for its upright growth and heavy seed-producing ability. The stake shown is used to support the screen bags used to prevent the entrance of insects when inbred seed is desired in line breeding.

PLATE IV. Fig. 1.—A field of Grimm alfalfa near Excelsior, Minn., showing the effects of ice sheets in February, 1906, which similarly injured many old stands of Grimm alfalfa which had been uninjured for thirty years. It will be noted that there is a direct relation between the topography of the field and the injury. Fig. 2.—A field of Canadian alfalfa, showing the effects of ice sheets in February, 1906, at which time many fields in the neighborhood experienced their first serious injury for fifteen years. Photograph taken near Wellandport, Ontario, Canada.

PLATE V. Fig. 1.—A field of Grimm alfalfa forty years old, seeded in 1869, near Excelsior, Minn. The immediate foreground, which borders a slough, has given way to native grasses. Fig. 2.—A field of ordinary alfalfa five years old, near Excelsior, Minn. Only a few plants have survived the winters.

PLATE VI. Fig. 1.—Field plots of commercial sand lucern (at the right) and of Grimm alfalfa (at the left), Dickinson, N. Dak. The minimum temperature during the preceding winter (1908–9) was —31° F. S. P. I. Nos. 21217 and 21269 (sand lucerns) are shown in the right foreground and in the background, respectively, with S. P. I. Nos. 21287 and 21735 (Montana-grown and Nebraska-grown Grimm alfalfa) in the left foreground and in the background, respectively. The center stake marks the meeting point of the four plots. Fig. 2.—Field plots of Utah alfalfa (in immediate foreground) and of commercial sand lucern (beyond), at Dickinson, N. Dak. A few square feet of the sand lucern plants (S. P. I. No. 21217) had been cut from the front of the plot in making some statistical studies just before the photograph was taken. The Utah alfalfa (S. P. I. No. 12784) shows a patchy stand owing to winterkilling.

PLATE VII. Fig. 1.—Cultivated rows of commercial sand lucern (at the left) and of Turkestan alfalfa (at the right), at Sextorp, Nebr. Both were grown in cultivated rows for seed in western Nebraska having a normal rainfall of 15 inches on upland without irrigation. Fig. 2.—Cultivated rows of commercial sand lucern (at the right) and of Brott's dry-land alfalfa (at the left) in the same field shown in figure 1.

PLATE VIII. Abnormal inflorescences in various strains of variegated alfalfa: *A*, Grimm alfalfa, showing same arrangement of racemes as in ordinary alfalfa, but with the two lower racemes abnormal branching; *B*, Grimm alfalfa, showing whorled racemes and crowded racemes near top of stalks; *C*, variegated alfalfa selected from Rocky Ford, Colo., showing supernumerary leaflets and racemes approaching the subcorymbose habit; *D*, variegated alfalfa (Wheeler alfalfa) from Bridgeport, Kans., showing subcorymbose racemes; *E*, commercial sand lucern, showing racemes crowded toward top of stalk. One of the lower racemes is forked.

PLATE IX. Abnormal inflorescences in various strains of variegated alfalfa in addition to those shown in Plate VIII: *A*, fruiting stem; *B*, flowering stem of plant of variegated alfalfa (Wheeler alfalfa), showing compound racemes crowded toward top of stalk; *C*, an abnormality found in Grimm alfalfa. The flowers are in compound racemes and crowded toward the top of the stalk; *D*, an abnormality found in variegated alfalfa (Wheeler alfalfa). The flower parts are reduced to minute bracts and closely crowded in doubly compound racemes. The mother plant bore an occasional perfect flower; *E*, an abnormality noted in a plant of alfalfa of unknown origin near Rocky Ford, Colo. Inbred seed of *A* and *B* occasionally produces plants showing abnormalities similar to *D* and *E*.

FIG. 1.—A MATURE PLANT OF MEDICAGO FALCATA, SHOWING NEARLY PROSTRATE HABIT.

FIG. 2.—A SINGLE PLANT OF INTERMEDIATE ALFALFA, SHOWING DECUMBENT STEMS.

FIG. 3.—PLANTS OF INTERMEDIATE ALFALFA IN A NURSERY ROW, SHOWING PARTIALLY PROSTRATE HABIT.

FIG. 4.—A SINGLE PLANT OF ORDINARY ALFALFA, SHOWING UPRIGHT HABIT.

FIG. 1.—A SINGLE PLANT OF COMMERCIAL SAND LUCERN, WITH THE STEMS SLIGHTLY DECUMBENT.

FIG. 2.—A SINGLE PLANT OF GRIMM ALFALFA, SHOWING A SLIGHT TENDENCY TOWARD PROSTRATISM.

FIG. 3.—A FIELD OF GRIMM ALFALFA NEAR ALMA, NEBR., SHOWING LODGING.

FIG. 1.—A NATURAL HYBRID ALFALFA PLANT.

FIG. 2.—A SINGLE PLANT OF GRIMM ALFALFA, SHOWING FAIRLY UPRIGHT GROWTH AND GREAT LEAFINESS.

FIG. 3.—TWO GRIMM ALFALFA PLANTS OF WIDELY DIVERGENT TYPES.

FIG. 4.—A SINGLE PLANT OF AN UPRIGHT SELECTION OF VARIEGATED ALFALFA.

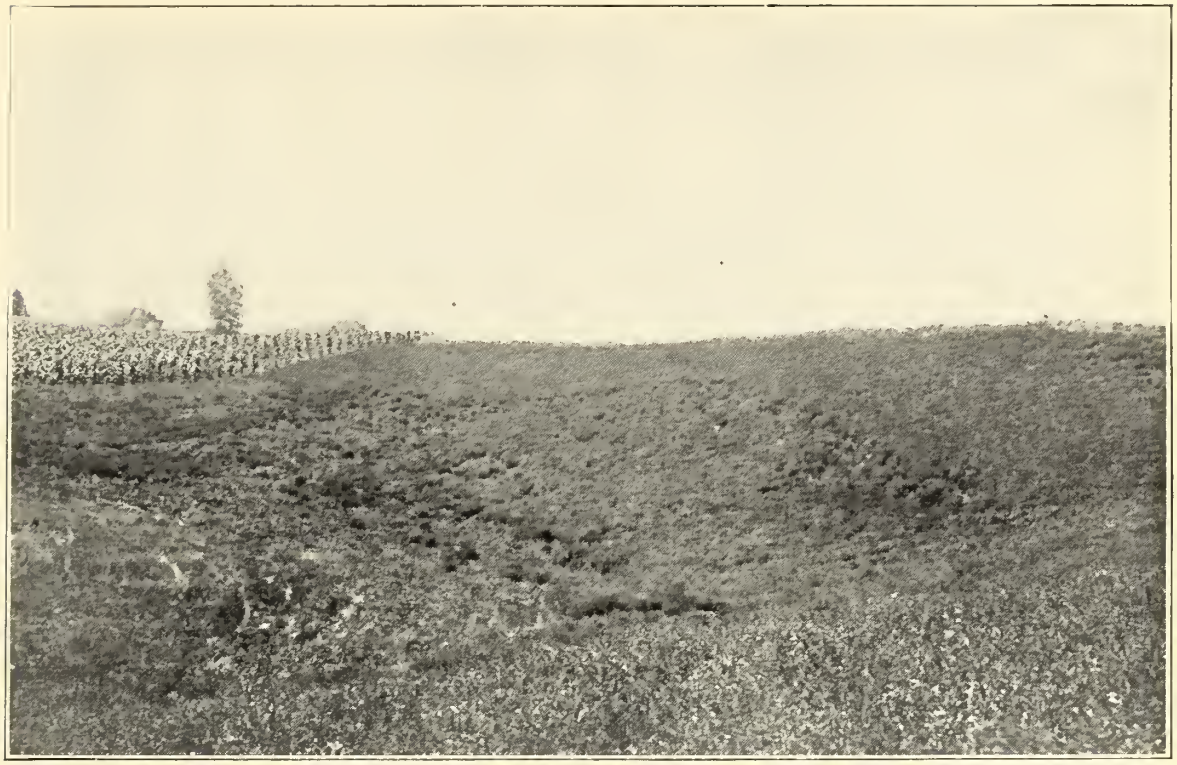

FIG. 1.—A FIELD OF GRIMM ALFALFA NEAR EXCELSIOR, MINN., SHOWING THE EFFECTS OF ICE SHEETS.

FIG. 2.—A FIELD OF CANADIAN ALFALFA, SHOWING THE EFFECTS OF ICE SHEETS.

FIG. 1.—A FIELD OF GRIMM ALFALFA FORTY YEARS OLD, NEAR EXCELSIOR, MINN.

FIG. 2.—A FIELD OF ORDINARY ALFALFA FIVE YEARS OLD, NEAR EXCELSIOR, MINN.

Only a few plants have survived the winters.

FIG. 1.—FIELD PLOTS OF COMMERCIAL SAND LUCERN (AT THE RIGHT) AND OF GRIMM ALFALFA (AT THE LEFT), AT DICKINSON, N. DAK.

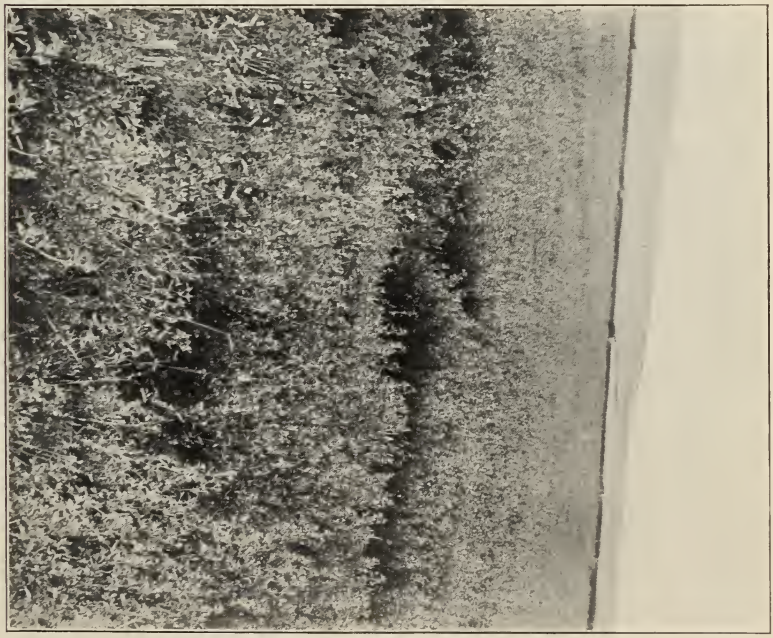

FIG. 2.—FIELD PLOTS OF UTAH ALFALFA (IN IMMEDIATE FOREGROUND) AND OF COMMERCIAL SAND LUCERN (BEYOND), AT DICKINSON, N. DAK.

FIG. 1.—CULTIVATED ROWS OF COMMERCIAL SAND LUCERN (AT THE LEFT) AND OF TURKESTAN ALFALFA (AT THE RIGHT), AT SEXTORP, NEBR.

FIG. 2.—CULTIVATED ROWS OF COMMERCIAL SAND LUCERN (AT THE RIGHT) AND OF BROTT'S DRY-LAND ALFALFA (AT THE LEFT) IN THE SAME FIELD SHOWN IN FIGURE 1.

ABNORMAL INFLORESCENCES IN VARIOUS STRAINS OF VARIEGATED ALFALFA.

ABNORMAL INFLORESCENCES IN VARIOUS STRAINS OF VARIEGATED ALFALFA, IN ADDITION TO THOSE SHOWN IN PLATE VIII.

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